NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ANALYSIS OF A LANCE MISSILE PLATOON USING A SEMI-MARKOV CHAIN

by

Harry M. Argo

September 1989

Thesis Advisor: Samuel H. Parry

lassified

ity classification of this page

REPORT DOCUMENTATION PAGE

eport Security Classification Unclassified	1b Restrictive Markings
ecurity Classification Authority	3 Distribution Availability of Report Approved for public release; distribution is unlimited.
eclassification Downgrading Schedule	
rforming Organization Report Number(s)	5 Monitoring Organization Report Number(s)
ame of Performing Organization val Postgraduate School — 6b Office Symbol (if applicable) 55	7a Name of Monitoring Organization Naval Postgraduate School
ddress (city, state, and ZIP code) nterey, CA 93943-5000	7b Address (city, state, and ZIP code) Monterey, CA 93943-5000
ame of Funding Sponsoring Organization — 8b Office Symbol (if applicable)	9 Procurement Instrument Identification Number
ddress (city, state, and ZIP code)	10 Source of Funding Numbers Program Element No · Project No · Task No · Work Unit Accession No

itle (include security classification) ANALYSIS OF A LANCE MISSILE PLATOON USING A SEMI-MARKOV CHAIN

ersonal Author(s) Harry M. Argo

Type of Report	13b Time Covered	14 Date of Report (year, month, day)	15 Page Count
ster's Thesis	From To	Sept 1989	98

upplementary Notation The views expressed in this thesis are those of the author and do not reflect the official policy or po-
on of the Department of Defense or the U.S. Government.

osati Codes			18 Subject Terms (continue on reverse if necessary and identify by block number)
d	Group	Subgroup	A stochastic model representing a Lance missile platoon in combat.

bstract (continue on reverse if necessary and identify by block number)

This thesis develops a combat effectiveness model for the Lance missile system. The survivability and ability to accom-
h the mission for a Lance missile launch platoon depends upon enemy capabilities, platoon configuration, missile reli-
ity and many other tangible factors. The changing status of a launch platoon is modeled using a semi-Markov chain with
sient and absorbing states. Expected number of missiles fired prior to absorption and expected time to absorption are the
sures of effectiveness used to analyze the effect of scenario input. Sensitivity analyses are conducted on the parameters
latoon configuration, missile reliability and fire point usage.

istribution Availability of Abstract nclassified unlimited ☐ same as report ☐ DTIC users	21 Abstract Security Classification Unclassified
Name of Responsible Individual uel H. Parry	22b Telephone (include Area code) (408) 646-2779 — 22c Office Symbol 55Py

FORM 1473,84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

security classification of this page

Unclassified

Approved for public release; distribution is unlimited.

Analysis of a Lance Missile Platoon using a Semi-Markov Chain

by

Harry M. Argo
Captain, U. S. Army
B.S., United States Military Academy, 1979

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
Sept 1989

ABSTRACT

This thesis develops a combat effectiveness model for the Lance missile system. The survivability and ability to accomplish the mission for a Lance missile launch platoon depends upon enemy capabilities, platoon configuration, missile reliability and many other tangible factors. The changing status of a launch platoon is modeled using a semi-Markov chain with transient and absorbing states. Expected number of missiles fired prior to absorption and expected time to absorption are the measures of effectiveness used to analyze the effect of scenario input. Sensitivity analyses are conducted on the parameters of platoon configuration, missile reliability and fire point usage.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would like to express my appreciation to the following people who made this thesis possible:

- Professor Samuel H. Parry for his guidance, inspiration and devotion to his students.
- Professor Patricia A. Jacobs for her wisdom and patience.
- Carol, Tom, Cindy and Dave whose prayers were answered.

Thank you very much.

I. INTRODUCTION

A. PERSPECTIVE OF LANCE AND THE AIR LAND BATTLE

What are the repercussions of the recent START agreement to eliminate Pershing II medium range missiles from Europe? Clearly, NATO is losing its most viable land based nuclear deterrent and defense against tactical aggression.

Exploring the current United States Military doctrine reveals further impacts of the decision. During the decade of the 1980s, U.S. military planners have developed and adopted the combat doctrine called Air Land Battle which relies on the ability to strike deep into enemy territory against second and third echelon forces. Elimination of Pershing II severely restricts the ability of existing forces to strike deep with nuclear weapons. This puts a heavy reliance upon air launched weapons and remaining Field Artillery assets to fulfill the mission.

Success in striking targets well behind enemy lines with Air Force assets is contingent upon air superiority, enemy air defence and weather conditions. Cannon Artillery is unhampered by these restrictions but lacks sufficient range and destructive power to meet the need. Our only alternative at this point is to optimize the use of an aging but reliable weapon system which can meet the range requirements with the necessary fire power: The Lance Missile.

The Army Tactical Missile System (ATACMS) is the future replacement for the Lance system and represents a vast improvement in range, mobility and lethality. Whether political diplomacy allows this replacement to occur in continental Europe is yet to be seen. Currently, however, Lance is the Army's only established long range, nuclear capable missile in Europe.

B. BASIC DESCRIPTION OF LANCE

Lance is a corps commander's primary long range artillery. It gives him an effective, all weather, day or night, nuclear or conventional weapon system which can engage priority targets deep in enemy territory. When at sea level, the system can range targets between 8 and 91 kilometers away with nonnuclear munitions and targets between 8 and 115 kilometers away with nuclear weapons.

1. The Missile

The missile is 6.14 meters long and has two subcomponents, the warhead section and the main missile assemblage. The warhead section is either nonnuclear (heavy)

consisting of grenades and bomblets which are effective agains soft targets or it is a nuclear warhead (light). The main missile assemblage is a liquid propellant rocket engine system with a inertial guidance system. When in flight the guidance system keeps the missile oriented on a constant direction and angle of assent and causes the rocket engine to cut off at a predetermined time. The missile then follows a ballistic trajectory to the target.

In preparation for firing, the missile must be programmed by an on board (launcher) computer with target parameters such as range and height of burst. The firing system for Lance missiles is extremely sensitive to enviromental influences such as humidity and temperature and also the precision with which it is handled. Thus, when attempting to fire the missile there is a probability of receiving a NO GO based upon these influences. The missile may still be operational but needs to be inspected and, if operational, refired.

2. The Launcher

Lance is fired from a self propelled launcher (M752) which is a highly mobile tracked vehicle that carries all needed fire control equipment. In the conduct of a fire mission the launcher is located over a surveyed position and oriented in the direction of fire. The missile is elevated upon an on board launch fixture, oriented for exact direction using a theodolite and survey technology and fired. The on board launch fixture can also be extracted from the self propelled launcher and used in another configuration for special operations, such as airmobile assault missions. Such operations are beyond the scope of this current model and are not considered or included.

3. The Loader-Transporter

The Loader-Transporter (M688) is a tracked vehicle similar to the launcher and is designed to assist the launch platoon in ammunition resupply. The Loader-Transporter carries two complete missiles and has a boom which it uses to transport missiles on to the launcher. The Loader-Transporter is as mobile as the launcher and can accompany it if necessary.

4. Firing Points

A Firing point is a tactical location that the launch platoon occupies and fires the missile from. Because of the long range of Lance and the relatively small probable error of the inertial guidance system, launch positions must be surveyed for location and directional control. Lance batteries are equipped with a survey section which has the capability of ensuring the following: an accuracy ratio of 1:1000 for position closure, $\pm$ 2 meters in height, and orienting azimuth accurate to $\pm$ .0.4 mils.

Normally the commander will choose fire points well in advance in order to allow the survey section sufficient time to establish survey control markers and provide survey data to the launch platoon. Naturally, if survey control markers are disturbed, removed or never emplaced, the launch platoon must either displace to another fire point or wait until survey control is reestablish.

5. Organization

A Lance missile launcher is operated by a launch platoon while two Loader-Transporters are operated by a Ammunition and Transport (A&T) platoon. There are two launch platoons and one A&T platoon in a Lance battery and there are three Lance batteries in a Lance battalion. The focus of this model will be the Lance launch platoon.

C. LANCE SURVIVABILITY

Because of Lance's extraordinary capabilities it has consistently been a high priority target for Warsaw Pact Nations. Questions are raised repeatedly in Lance survivability studies about Lance's longevity on the battlefield and its survivability. Lance units will receive special attention from enemy target aquisition assets and can expect attacks from enemy artillery, aircraft and ground units.

1. Artillery Attack

The high signature of the missile when fired makes Lance extremely vulnerable to Field Artillery cannon or missile counter battery fire. When fired the missile travels with an extremely high trajectory, makes a continuous loud noise and leaves a visible trail of smoke. This enables enemy acquisition units to locate the launch point quickly and accurately, as well as giving all enemy assets in the vicinity a good idea of the location of the source of firing. Cannon or missile attack is then the quickest method of attack expected.

2. Air Attack

If the enemy has air reconnaissance and air strike capabilities, Lance units become extremely vulnerable while traveling, transloading and preparing to fire. Launch platoons will always maximize cover and concealment but some operations, such as transloading, require large open space and are more visible and vulnerable to detection from the air.

3. Ground Attack

Although Lance units are placed behind forward combat units, they are not safe from ground attack. Often launch platoons will be sent forward where vulnerability to detection and attack is higher in order to range deep targets. Enemy long range special

operation patrols (SPETZNAZ) have the specific mission of locating and destroying high priority targets which include nuclear capable Lance units. These patrols can be expected to infiltrate rear areas and search out likely locations that Lance units would use for firing, hiding or carrying out other missions. Once a fire mission has been successfully conducted, the signature of the missile will give any patrols in the vicinity a clear advantage in detecting the Lance units. Even when the Lance units are detected by other means, SPETZNAZ patrols are expected to quickly be assigned the mission of finding and destroying such units.

II. OBJECTIVE

A. A BETTER MODEL

In light of Pershing's demise, Lance missile units will be greatly relied upon as a tactical nuclear deterent. Thus, optimal utilization of Lance is essential. The objective of this research is to develop a model of a Lance launch platoon using a semi-Markov process in order to assist planners and decision makers in the evaluation of Lance's effectiveness and survivability on the battlefield.

This model is prescriptive in the sense that it will be oriented towards battle planning and wartime operations. It can, however, be used in a descriptive role when incorporated into larger combat models. The actual function of the model is to analyze the effect of different sets of assumptions and inputs which describe tactical configurations and battlefield environments. One goal of this model is to provide a tool for evaluation of the effectiveness of tactics which are costly to execute in training.

B. MODEL INPUTS

The effectiveness of battle contingencies and procedures for the following situations cannot be effectively evaluated. It is impossible to test each combat contingency or plan for all possible combat situations. This model incorporates these situations as model inputs in order to evaluate their effect.

1. Use of fire points

Often the commander must decide whether to use only fire points which are unused and undetected or to send a launch platoon to fire points which have been fired from or are presumed to be detected. For this model a launch platoon on an undetected point has a probability of becoming detected while a launch platoon on a detected point has a probability of being destroyed. Fire points are chosen by the commander or platoon leaders and are surveyed by the survey platoon before use. In the context of this model, it is assumed that fire points can be produced quickly enough that the commander can maintain a constant percentage of unused or undetected fire points independent of the speed of the battle. Although this is seemingly a departure from realism, it enables the model to render guidance concerning the use of detected fire points. Further attention of this matter is left for further refinement of the model.

2. Travel Routes

A perpetual dilemma for military planners is the choice of routes. The commander often has a mission which is time critical and must choose between fast routes with high vulnerability or slower, less vulnerable routes. He must issue guidance which will best accomplish his mission. In this model the attributes of the routes are entered as expected travel time and the probability of being destroyed on the route.

3. Rate of Defective Missiles

Because of the age and technology of Lance there may be a high occurrance of intitial NO-GOs when firing the missiles due to environmental factors, such as temperature and humidity. or even a high percentage of defective missiles. With this model the user can input the probability of a first time NO-GO and the probability that a missile which initially received a NO-GO is not defective and will fire on subsequent attempts. As a result the commander can then see the larger impact of a high defective rate upon effectiveness. He can then search for procedures and configurations which optimize effectiveness in light of a high defective missile rate.

4. Enemy Detection Capabilities

The enemy's capability to locate Lance units can vary immensely. The enemy may be well equipped and highly trained or ill equipped, fatigued and ineffective. Based on the intelligence estimate the user can input information to reflect the Lance platoon's vulnerability to detection and also to ensuing artillery, air or ground attack during operations.

5. Operational Readiness of Organic Equipment

Equipment breakdown, specifically vehicular breakdowns, will impact greatly upon combat effectiveness of a Lance platoon. Poor or insufficient attention to equipment maintenance will mean more frequent breakdowns and consequently higher vulnerability to attack and lower effectiveness. In the model the user can enter the probability of vehicular breakdown while traveling and observe the effects.

6. Platoon configuration

How will launch platoon configuration with respect to the Loader-Transporter affect vulnerability and effectiveness for different situations? The Lance platoon may be configured with a Loader-Transport which allows the platoon to reload immediately. The model allows three configurations which are explained in detail in Chapter V.

Often a launch platoon is ordered to lay the missile and wait until a specific command to fire is given as opposed to firing at a predetermined time or when ready. This method of fire may increase the vulnerability to detection and destruction depend-

ing upon the amount of time a launch platoon must wait. The model provides for this aspect of operations.

C. MODEL OUTPUT

There are two outputs of this model which are desirable measures of effectiveness (MOE) for the decisions input into the model. The user can manipulate environmental or decision variables in order to observe their effects on an MOE or pursue optimality of the MOE.

1. Measure of Effectiveness One

The first measure of effectiveness is the number of missiles that are fired before the Lance platoon is destroyed.

2. Measure of Effectiveness Two

The second measure of effectiveness is the amount of time that the Lance platoon survives in combat. This may be of greater importance than number of missiles fired if longevity of nuclear capable assets is critical.

D. STOCHASTIC/ANALYTICAL APPROACH

A stochastic process is used in this thesis to model the Lance platoon because the successive operations of a Lance platoon in combat can be easily represented by a discrete time Markov Chain.

1. Nature of Lance

In combat a Lance platoon conducts operations in definitive states and continually transitions from one type of operation to another. This model represents these operations states. The platoon will begin operating in a state, and remain in that state until the objective of that state is completed or until an event occurs which causes the platoon to leave the state prematurely and enter another. For example, if the platoon is in the state of traveling to a fire point, there is a probability that it arrives at the fire point; the state may then change to laying the missile. There is also a probability of being attacked and destroyed en route to the fire point, which means transitioning to an absorption state. From each state the platoon has a probability of transitioning to other states. The transition probabilities are based on the tactical situation and commanders guidance. Many of these states are reported to the battery Fire Direction Center (FDC).

2. Analytic Solution

There is an advantage to using a stochastic, analytic model instead of a simulation. This stochastic model is an analytical analysis of the situation and not an at-

tempt to create possible outcomes by generating situations using a Monte Carlo process. According to Leibholz in *Military Modeling*

> "A well-executed analytical model can provide answers in less than prodigal time -- answers both as sound and as defensible as any simulation...A simulation model can represent more complex situations and interactions than a corresponding analytical model. However, it is inevitably more expensive and less flexible than the analytical model, and introduces simulation noise into the results." [Ref. 1: p. 339]

a. Run time

The model MOE's are obtained numerically. The numerical operations are primarily matrix manipulation and inversion. APL 2.0 takes about two seconds of run time to achieve a solution once the the input data have been entered or manipulated. There is also no need for replication because this is not a Monte Carlo simulation.

b. Versatility

There are other weapons systems which are similar to the Lance Missile delivery system which could adopt a variation of a Lance model for combat analysis. For example, the Patriot air defense missile and the Multiple Launch Rocket System (MLRS) operate in fashions similar to Lance, especially with respect to transitioning states. The Army Tactical Missile System (ATACMS), the future replacement for Lance, is a variation of the MLRS weapon system and will be easily modeled using an adaptation to a MLRS model. It is hoped that interest in analytical models for these weapon systems will be enhanced by this model for Lance.

3. Feeder for Other Models

An additional objective of this model is to create a feeder for higher level aggregated combat models. In the hierarchy of Army combat models "analytic models are frequently employed as the lower-level combat models internal to the higher-level models. To perform this role and provide a useful model of higher-echelon operations, it is very desirable that such models have very short running times."[Ref. 1: p.156] Not only is this type of model quick but the inputs and outputs could be the linked to other similar models to enable interaction between entities on the battlefield.

4. Detail

With this type of model, many variables can be included and easily manipulated for evaluation, adding resolution and complexity with an increase in the number of factors. However, the output will still be a quick and accurate analytical solution.

III. METHODOLOGY

A. MARKOV CHAINS

Much has already been stated in this text about how the Lance system operates in states. The successive states that a Lance platoon is in can be modeled by a disrete time Markov process. A definition of a Markov process is offered by Taylor and Karlin in "An Introduction to Stochastic Modeling":

"A *Markov Process* $\{X_t\}$ is a stochastic process with the property that, given the value of X_t , the values of X_s for $s > t$ are not influenced by the values of X_u for $u < t$. In words, the probability of any particular future behaviour of the process, when its current state is known exactly, is not altered by additional knowledge concerning its past behavior. A *discrete time Markov chain* is a Markov process whose state space is a finite or countable set, and whose (time) index set is $T = \{0, 1, 2, \ldots\}$. In formal terms, the Markov property is that

$$\Pr\{X_{n+1} = j \mid X_0 = i_0, \ldots, X_{n-1} = i_{n-1}, X_n = i\}$$
$$= \Pr\{X_{n+1} = j \mid X_n = i\} \tag{1}$$

for all time points n and all states $i_0, \ldots, i_{n-1}, i, j$. The probability of X_{n+1} being in state j given that X_n is in state i is called the *one-step transition probability* and is denoted by $P_{ij}^{n,n+1}$. That is,

$$P_{ij}^{n,n+1} = \Pr\{X_{n+1} = j \mid X_n = i\} \tag{2}$$

The notation emphasizes that in general the transition probabilities are functions not only of the initial and final states, but also of the time of transition as well. When the one-step transition probabilities are independent of the time variable n, we say that the Markov chain has *stationary transition probabilities.*" [Ref. 2: p. 67]

The successive states of a Lance platoon will be modeled by a discrete time Markov Chain. For the Lance model, the probability of the platoon transitioning from state i to state j in the n^{th} time transition step is

$$P_{ij}^{n,n+1} = P_{ij} \tag{3}$$

meaning that the probability of transitioning to a state in one step depends only upon the state where it is presently operating, independent of what transition it is. The *State Space* refers to all possible states in which the launch platoon can exist.

The values of P_{ij} for a discrete time Markov chain are customarily arranged in a matrix similar to the following example which represents a state space of five states {0, 1, 2, 3, 4,}:

$$
\mathbf{P} = \begin{vmatrix} P_{00} & P_{01} & P_{02} & P_{03} & P_{04} \\ P_{10} & P_{11} & P_{12} & P_{13} & P_{14} \\ P_{20} & P_{21} & P_{22} & P_{23} & P_{24} \\ P_{30} & P_{31} & P_{32} & P_{33} & P_{34} \\ P_{40} & P_{41} & P_{42} & P_{43} & P_{44} \end{vmatrix} \tag{4}
$$

This matrix **P** is known as the *Probability Transistion Matrix*.

The quantities P_{ij} must satisfy the following conditions:

$$
P_{ij} \geq 0 \quad for \;\; i,j = 0, 1, 2, \ldots,
$$

$$
\sum_{j=0}^{\infty} P_{ij} = 1 \quad for \;\; i = 0, 1, 2, \ldots, \tag{5}
$$

In words, all P_{ij} values must be nonnegative and add to one across a row.

A discrete time Markov chain is completely defined once its transition probability matrix and initial state X_0 (or, more generally, the probability distribution of X_0) are specified. In the Lance application, the probability distribution of X_0 for this model can differ according to the tactical situation.

B. SEMI-MARKOV PROCESS

The Lance model is actually a semi-Markov process. A Semi-Markov process differs from the discrete time Markov chain in that the process may sojourn in a state i for a random time with mean μ_i before transitioning to another state j, independent of how the process arrived at state i. [Ref. 3: p. 292] For the Lance model, all sojourn times considered are mixtures of constant times. Each constant time is dependent upon i, the present state of the process, and j, the state to which the process is transitioning. The mean value of the sojourn time, μ_i, is given by the relationship:

$$
\mu_i = \sum_{j=0}^{N} P_{ij} t_{ij} \tag{6}
$$

where t_{ij} is a constant representing the sojourn time in state i when after the next transition the process is in state j. P_{ij} is the probability of transitioning from state i to state j. Developing a $\mathbf{T}_{ij}$ matrix for the Lance model is addressed later in this thesis.

C. EVALUATION OF MOMENTS FOR AN ABSORBING MARKOV CHAIN AND AN ABSORBING SEMI-MARKOV PROCESS

Taylor and Karlin derive and explain the evaluation of moments for an absorbing Markov process and an absorbing semi-Markov process.

> "Consider a Markov Chain whose states are labeled 0, 1, . . . ,N. States 0, 1, . . . , $r-1$ are transient in that $P_{ij}^{(n)} \to 0$ as $n \to \infty$ for $0 \le i,j < r$ while states r, . . ., N are absorbing, or trap, and here $P_{ii} = 1$ for $r \le i \le N$. The transition matrix has the form
>
> $$\mathbf{P} = \begin{vmatrix} \mathbf{Q} & \mathbf{R} \\ \mathbf{0} & \mathbf{I} \end{vmatrix} \tag{7}$$
>
> where 0 is an $(N-r+1) \times r$ matrix all of whose components are zero. I is an $(N-r+1) \times (N-r+1)$ identity matrix and $Q_{ij} = P_{ij}$ for $0 \le i,j < r$".[Ref 2: p.116]

They then develop the fundamental matrix, **W**, which is defined as

$$\mathbf{W} = (\mathbf{I} - \mathbf{Q})^{-1}. \tag{8}$$

The values w_{ij} of **W** are the expected number of visits to state j before absorption given that the Markov chain initially started in state i.. [Ref. 2: pp.117-118]

Using μ as a column vector of the expected sojourn times we obtain the expected times to absorption for the semi-Markov model from the relation

$$\mathbf{T}_{abs} = \mathbf{W}\mu \tag{9}$$

The expected time prior to absorption given that the semi-Markov process started in state i is equal to $w_{ij}\mu_i$

Once the transition matrix for Lance is arranged in accordance with equation 7, these relationships are used in this thesis to evaluate the semi-Markov chain. The mathematical relationships are incorporated into an APL program, **SOLVE** (Appendix M), which is used to solve for the expected number of times the process visits a state (Missile shot) and the expected time until absorption. For this model the semi-Markov process begins in states which represent a launch platoon prior to battle. All executions of the programs assume that the launcher starts in hiding at an undetected fire point waiting for a fire mission with a missile on board.

IV. MODEL FORMULATION

A. APPROACH

The approach used in building this model is to take Lance tactics and technical procedures and represent them as states in a Markov Chain. As mentioned earlier, Lance operations can be represented as discrete events because the platoon is capable of conducting only one operation at a time. For example, the platoon cannot lay the missile and travel simultaneously. The Markov Chain in this model is a series of states which represent all possible tactical situations.

B. TACTICS

As with all Field Artillery units, the pro-words which describe Lance's tactical objectives are "SHOOT, MOVE, AND COMMUNICATE." All decisions made in combat concentrate on these three objectives in order to maximize artillery fires and increase survivability.

1. Tactical Configurations

Depending upon the tactical situation, the Lance platoon can take three different configurations which relate to the attachment of a Loader-Transporter.

a. Configuration One

In the first configuration the Loader-Transporter accompanies the launch platoon to the fire points so that new missiles can be transloaded onto the launcher immediately.

b. Configuration Two

In the second configuration a Loader-Transporter operates with the launch platoon but is positioned at a local transload point in the general vicinity while the launch platoon conducts a mission at the fire point.

c. Configuration Three

In the third configuration the launcher operates without a Loader-Transporter and is therefore required to travel to the central transload point each time a new missile is required.

2. Ammunition

The Lance missile launcher can carry only one missile at a time while the Loader-Transporter can carry two. Therefore, there are three possible ammunition configurations in which the platoon can operate which depend upon the tactical config-

uration. In this model these ammunition configurations are represented by three *levels* of activity which are similar except for the ammunition status. Once a missile is fired (or rejected) the launch platoon transitions to a state which is in a lower level of activity. Once the platoon is replenished it moves to a higher level of activity. This organization into levels simplifies computation of the P matrix.

- Level One: The launch platoon is in tactical configuration one or two and has one missile on the launcher and two missiles on an accompanying Loader-Transporter.
- Level Two: The launch platoon is in tactical configuration one or two and has one missile on the launcher but only one missile on an accompanying Loader-Transporter.
- Level Three: The launch platoon has only one missile on the launcher and no missiles on the Loader-Transporter.

C. EXPLANATION OF TERMS

The following terms are used in explaining states involved in this model.

- Hide: The Launch Platoon is near the fire point camouflaged to decrease vulnerability.
- Lay: Launcher is placed over a surveyed position and oriented for direction. All firing procedures are conducted and the missile is raised to firing elevation.
- Shoot: The missile leaves the launcher.
- Misfire: The launch platoon attempts to shoot the missile but encounters a technical difficulty. This may be due to improper handling procedures, a defective missile or an electronic malfuntion (NO-GO).
- Transload: Operation of lifting a missile from the Loader-Transporter and placing it onto the launcher. This can be done anywhere there is room enough to pull the vehicles together. In this model the platoon conducts transload operations in accordance with the tactical configuration.

V. DEVELOPING THE PROBABILITY TRANSITION MATRIX (PIJM)

A. METHODOLOGY

The burden of work in producing the Lance model was in developing the state space. This was a process of ensuring that all tactical situations which are to be modeled are represented by a state. It is of critical importance that the state space represents a Markov chain as described in Chapter III. Each state can represent only one unique set of circumstances.

Once the state space is defined, **P**, the probability transition matrix can be developed. This was done by writing a series of APL programs which create a zero matrix corresponding to the size of the state space and then fill the appropriate entries with the values of P_{ij}

B. STATE SPACE

Ninety-three states are needed in this model to represent Lance missile platoon operations. The first eighty-eight are transition states and the last five are absorption states.

1. Transition States

The eighty-eight transition states are arranged into three levels of activity which have similar characteristics with respect to tactics but differ in ammunition status.

For ease in explaining and reviewing concepts in this thesis and manipulating matrices in APL, the initial state is designated as state one. Thus the transition matrix **P** for the Lance model takes the form:

$$\mathbf{P} = \begin{vmatrix} P_{11} & P_{12} & \cdot & \cdot & P_{1\,93} \\ P_{21} & \cdot & & & \cdot \\ \cdot & & \cdot & & \cdot \\ \cdot & & & \cdot & \cdot \\ P_{93\,1} & \cdot & \cdot & \cdot & P_{93\,93} \end{vmatrix} \tag{10}$$

a. Level One

The first level (states 1 to 33) represents all possible states which can occur when a launch platoon is accompanied by a Loader-Transporter (LT) carrying two ad-

ditional missiles. Appendix A consists of tables which give explicit descriptions of the states in the first level of activity.

- States 1 to 8 represent the Lance platoon when conducting fire operations at an undetected fire point. (Tables 6 and 7)
- States 9 to 19 represent the Lance platoon when conducting fire operations at a detected fire point. (Tables 8 and 9)
- States 20 to 33 represent the Lance platoon when conducting transload operations. (Tables 10 and 11)

b. Level Two

The second level (states 34 to 66) is similar to the first except the Loader-Transporter is carrying only one additional round, because the other has been fired or found defective. Appendix B consists of tables which describe states in the second level of activity.

- States 34 to 41 represent the Lance platoon when conducting fire operations at an undetected fire point. (Tables 12 and 13)
- States 42 to 52 represent the Lance platoon when conducting fire operations at a detected fire point. (Tables 14 and 15)
- States 53 to 66 represent the Lance platoon when conducting transload operations. (Tables 16 and 17)

c. Level Three

The third level (states 67 to 88) represents all possible states which can occur when a launch platoon has no additional missiles. Appendix C consists of tables which describe states in the third level.

- States 67 to 74 represent the Lance platoon when conducting fire operations at an undetected fire point. (Tables 18 and 19)
- States 75 to 85 represent the Lance platoon when conducting fire operations at a detected fire point. (Tables 20 and 21)
- States 86 to 88 represent the Lance platoon when conducting transload operations at the battery area. (Table 22)

The three levels of states are interrelated by transition probabilities which lead from one level of ammunition status to another as missiles are fired or rejected as defective. The transition from one level of activity to another occurs only from transload states.

2. Absorption States

States 89 to 93 are the absorbing states which represent destruction or neutralization of the launch platoon by enemy attack. Once the process arrives in an

absorbing state, it never exits the state. Thus the probability of staying an absorbing state is always one. The absorbing states are listed in Appendix D.

C. INTERACTIVE APL PROGRAMS

Assigning all transition probabilities and transition times for each of the 93 states includes up to 2700 entries and is clearly time intensive. More importantly, the user of such a model must assess each transition probability and transition time in order to enter a realistic value for each entry. Although possible, such a task is too labor intensive for multiple situations and would not be worth the effort required to run the model.

1. APL Program "PROGVAR"

In order to make this task easier for the user and allow expedient manipulation of matrix values, APL program PROGVAR creates the 93 by 93 matrix and prompts the user to enter the platoons's current tactical configuration. PROGVAR then elicits from the user a series of probabilities related to independent tactical events. The **P** matrix represents only one tactical configuration at a time. Therefore, transition probabilities related to other than the current tactical configurations will be assigned a value of zero. The events referred to are not states but rather tactical events which, when combined with other tactical events, are used to produce the probability of transitioning from one state to another.

Many of the user decisions are entered as events in PROGVAR, such as aborting a mission, that are not represented as a specific state. The programmer enters the probabilities of these events occuring (eg., the probability of being destroyed while traveling to a fire point) as a decimal value between zero and one. Appendix E gives a description of each input along with values used in this analysis as a basic scenario. Appendix G is a listing of the APL language for PROGVAR.

PROGVAR stores this information in a vector (VAR) and calls three other programs, PROG1MTX, PROG2MTX AND PROG3MTX, to compile **P**, the probability transition matrix. These three programs use basic laws of probability and the assumption of independence between events to calculate a tree of P_{ij} values. An example is given in Figure 1.

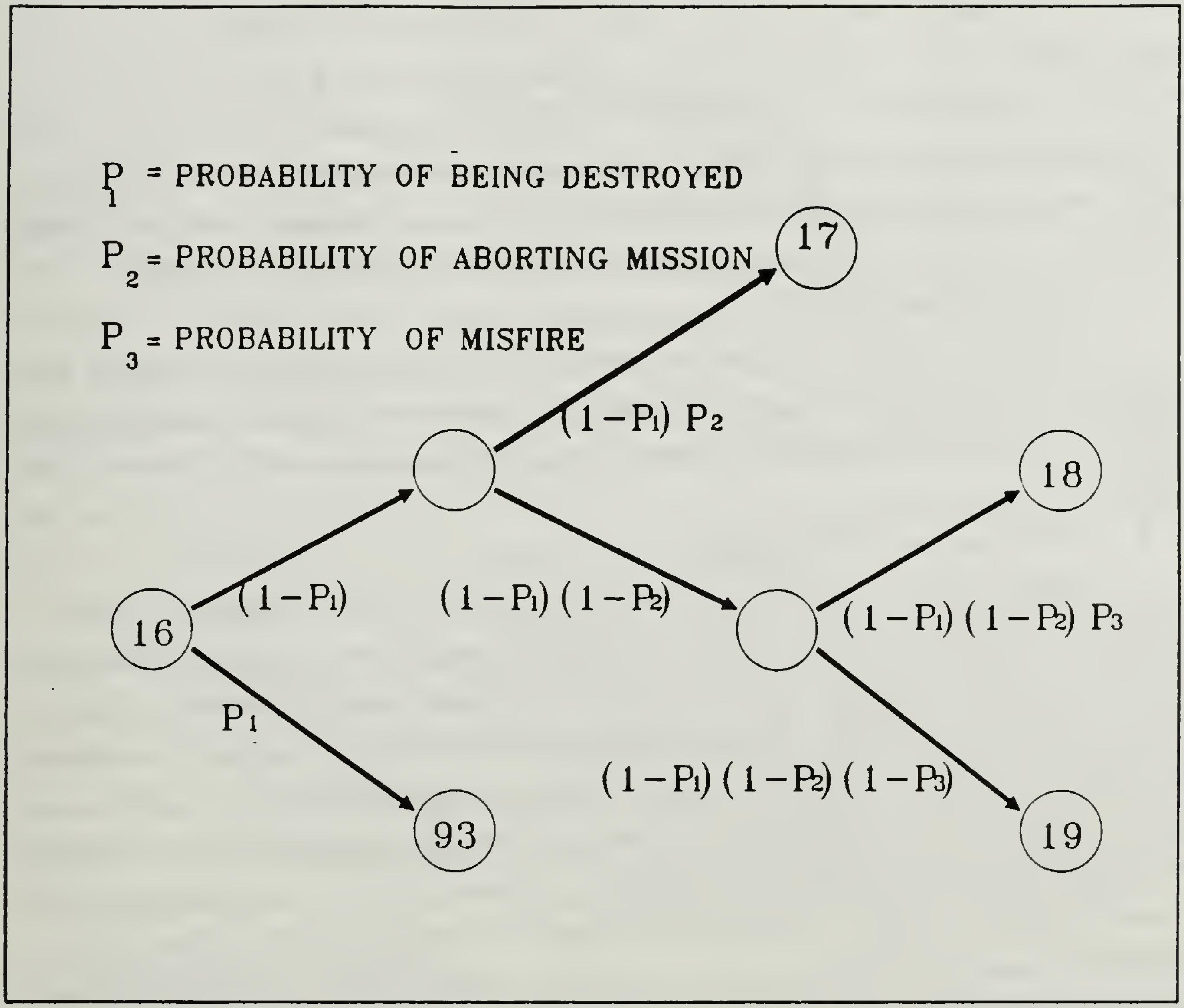

Figure 1. Example of the Probability Tree for State 16.

Through this method of computing P_{ij}, the addition of all entries in the **P** matrix across a row always equals one. The advantage of this methodology is that vector entries can be easily manipulated for analysis and the entire **P** matrix adjusted accordingly. This precludes the user from reentering all event data before every execution of the program. PROG1MTX, PROG2MTX AND PROG3MTX are listed in Appendices H, I, and J, respectively.

2. APL Program "PROGTIME"

The program PROGTIME creates the Time Transition matrix (TIJM in APL) in a fashion similar to PROGVAR's methodology. The program prompts the user to enter the amount of time in minutes that a specific type of event is expected to take and

enters the information into a vector (TIME). An explanation of PROGTIME's individual inputs and the values used for the basic scenario are given in Appendix K. PROGTIME then calls another program, TIMEMTX (Appendix L), which enters the information stored in vector TIME into the appropriate locations of the **T** matrix. Again, because the information is stored in a vector before the matrix is compiled, the entries in the vector are easily manipulated and the **T** matrix adjusted accordingly.

3. APL Program "SOLVE"

Once the **P** and **T** matrices are completed, APL program SOLVE uses the methodologies described in Chapter III to solve for the expected number of missiles fired before absorption and the expected time, in hours, until absorption. SOLVE is listed in Appendix M.

4. APL Program "CONFIGURE"

Program CONFIGURE was written to assist the user to change the tactical configuration of the *P* matrix. After CONFIGURE prompts the user to enter the configuration, it adjusts certain variables in vector VAR which act as switches. These switches cause the probability of transitioning to states which are not allowed in a configuration to be zero. For example, a launch platoon in configuration two or three is not accompanied to the fire point by a Loader-Transporter. Therefore, it is prohibited from transitioning to the states which represent the launch platoon transloading while en route to a fire point. CONFIGURE then calls PROG1MTX, PROG2MTX, PROG3MTX and TIMEMTX in order to create new **P** and **T** matices. CONFIGURE is listed in Appendix N.

VI. ANALYSIS

The purpose of this chapter is to demonstrate the transparency and sensitivity of the model to selected input parameters. Large numbers of runs were conducted to ensure that the trends exhibited from parameter variations satisfied the "military judgment" validation test. Only a few of these are presented in this chapter. In each case, the results of the parameter variations over the three configurations and two MOE's are presented. In addition, "military judgement" is applied to describe why the results occurred and to emphasize the transparency of model results to input variations. With this model the commander has the ability to observe the effect of external variables as well as choices he might make as a tool to help him make decisions.

Once the Lance model was completely developed in the APL computer language, the sensitivity of the model to changing scenarios became evident through use. Retracing the Markov chain lent great credibility to the output and showed that there is an attainable explanation for each result. Evaluation of Lance in likely combat scenarios showed that varying some input parameters impacted significantlv on one or both Measures of Effectiveness (MOEs). In order to present this sensitivity, a basic scenario was entered and three variations of the scenario were manipulated and examined.

A. BASIC INPUT SCENARIO

In the interest of time, information availability and document classification, the author developed subjective input values for programs PROGVAR and PROGTIME based on his experience with Lance units (see Appendix B). Classified data for input values are not used for this presentation. Instead, the focus of this analysis is directed towards the function of the model. Thus, conclusions drawn about Lance operations for this analysis apply only for this scenario. The input data remain constant throughout this chapter except for explained manipulations which were made for demonstration purposes. All time inputs are in minutes but, in order to better observe performance, the output (MOE Two) is in hours. The basic scenario is listed in Appendices E and F.

B. ASPECT ONE: TACTICAL CONFIGURATION

The first aspect considered was tactical configuration. The program was run three times, once for each tactical configuration, using the basic input scenario. The results are recorded in Table 1.

Table 1. RESULTS FOR BASIC SCENARIO

MEASURES OF EFFECTIVENESS	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
EXPECTED NUMBER OF ROUNDS FIRED	9.063941229	7.99255627	7.552638371
EXPECTED TIME UNTIL ABSORPTION	23.33518396	21.9466782	25.98754782

1. MOE One

The commander choosing a configuration which maximizes the number of missiles fired will look for the configuration with the highest value for the first Measure of Effectiveness. For MOE One, the expected number of missiles fired prior to being destroyed (absorption), Configuration One ranked highest and Configuration Three, lowest. Therefore, choosing Configuration One allows the launch platoon to fire one more missile (expected value) than the better of the other two configurations (Configuration Two).

Configuration One outperformed the others in the expected number of missiles fired because the launch platoon moves less frequently. After a fire mission the launch platoon in Configuration Two or Three must move once to the transload point or battery area and then back to a fire point. In Configuration One the launch platoon moves only once to the next fire point while transloading en route, but might not move at all if it transloads on the fire point. For this scenario the vulnerability to destruction associated with these movements outweighed the vulnerability associated with transloading at or en route to a fire point.

2. MOE Two

For MOE Two, Configuration Three ranked the highest because it takes much longer in this configuration to fire a missile. Effectively, the launch platoon spends more time traveling than it does shooting while in this configuration.

3. Trade Off

This example presents a trade-off for the commander to consider. In choosing Configuration Three over Configuration One he gains 2.6 hours expected survival time

but loses the ability to fire an expected value of 1.5 missiles. He must evaluate this trade-off based on his current and anticipated future missions.

The ratio of MOE Two to MOE One gives the average rate at which the launch platoon fires a missiles.

- Configuration One fires one missile every 2.57 hours.
- Configuration Two fires one missile every 2.75 hours.
- Configuration Three fires one missile every 3.44 hours.

These rates are reasonable with respect to the input scenario. Notice that Configuration Three's rate reflects a greater travel time to and from the fire points per missile fired. Also note that the number of missiles fired for Configuration Three is very close to that of Configuration Two. One would expect Configuration Two to fire more missiles than Configuration Three because the rate of fire is higher. Scrutiny of the input values revealed the vulnerability during transload at a local transload point (Configuration Two) to be significantly higher than for the battery area (Configuration Three). This allowed a platoon in Configuration Three to survive long enough to make up for a slow rate of fire.

C. ASPECT TWO: MISSILE RELIABILITY

The next example relates to Lance operations as missile reliability is diminished. Missile reliability in this model is the probability that a missile will fire. Quantitatively, the *defective rate* is defined as the product of the probability of receiving a first time NO-GO (misfire) and the probability that the missile will *not* fire on subsequent attempts (one minus the probability that it will fire on subsequent attempts).

There is an infinite number of combinations of these factors for each defective rate and each combination will have a different effect upon the output, because each of these events occur at different locations in the sequence of events. For this analysis, the input values for the probability of first time NO-GO (Input 45) and the probability that a missile which was a first time NO-GO, is not defective (Input 46) were adjusted from the base scenario and the results examined. No other parameters were changed.

1. Decreased Missile reliability

First, Input 45 was raised from 0.1 to 0.5 while Input 46 was lowered from 0.9 to 0.5. This represents an increase in the overall defective missile rate from 0.01 (basic scenario) to 0.25. The results in Table 2 show that MOE One *decreased* and MOE Two *increased* for all configurations.

Table 2. RESULTS FOR DECREASED MISSILE RELIABILITY

MEASURES OF EFFECTIVENESS	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
EXPECTED NUMBER OF ROUNDS FIRED	7.451501549	6.10096669	5.731946904
EXPECTED TIME UNTIL ABSORPTION	26.34540619	23.61342	27.75499831

These results are understandable since the platoon will spend more time traveling and transloading missiles than before and will have fewer successful fire missions. Because there are fewer missiles fired per attempt, vulnerability to enemy detection and subsequent attack are reduced, increasing expected longevity. The increase in the average time taken to fire a missile verifies this result.

- Configuration One fires one missile every 3.54 hours.
- Configuration Two fires one missile every 3.87 hours.
- Configuration Three fires one missile every 4.84 hours.

2. Further Decreased Missile Reliability

Table 3 contains the results of further increasing Input 45 from 0.5 to 0.7 and lowering Input 46 from 0.5 to 0.3. This brings the overall defective missile rate to 0.49.

Table 3. RESULTS FOR FURTHER DECREASED MISSILE RELIABILITY

MEASURES OF EFFECTIVENESS	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
EXPECTED NUMBER OF ROUNDS FIRED	5.480399651	4.170413349	3.897018815
EXPECTED TIME UNTIL ABSORPTION	28.84828288	24.56319541	28.86386458

MOE One continued to decrease and MOE Two continued to increase for all configurations. The times taken to fire have increased, as can be expected.

- Configuration One fires one missile every 5.26 hours.
- Configuration Two fires one missile every 5.88 hours.
- Configuration Three fires one missile every 7.41 hours.

3. Overview

Figures 2 and 3 provide the reader visual representations of what happens to the MOEs as the two parameters concerning missile reliability are varied.

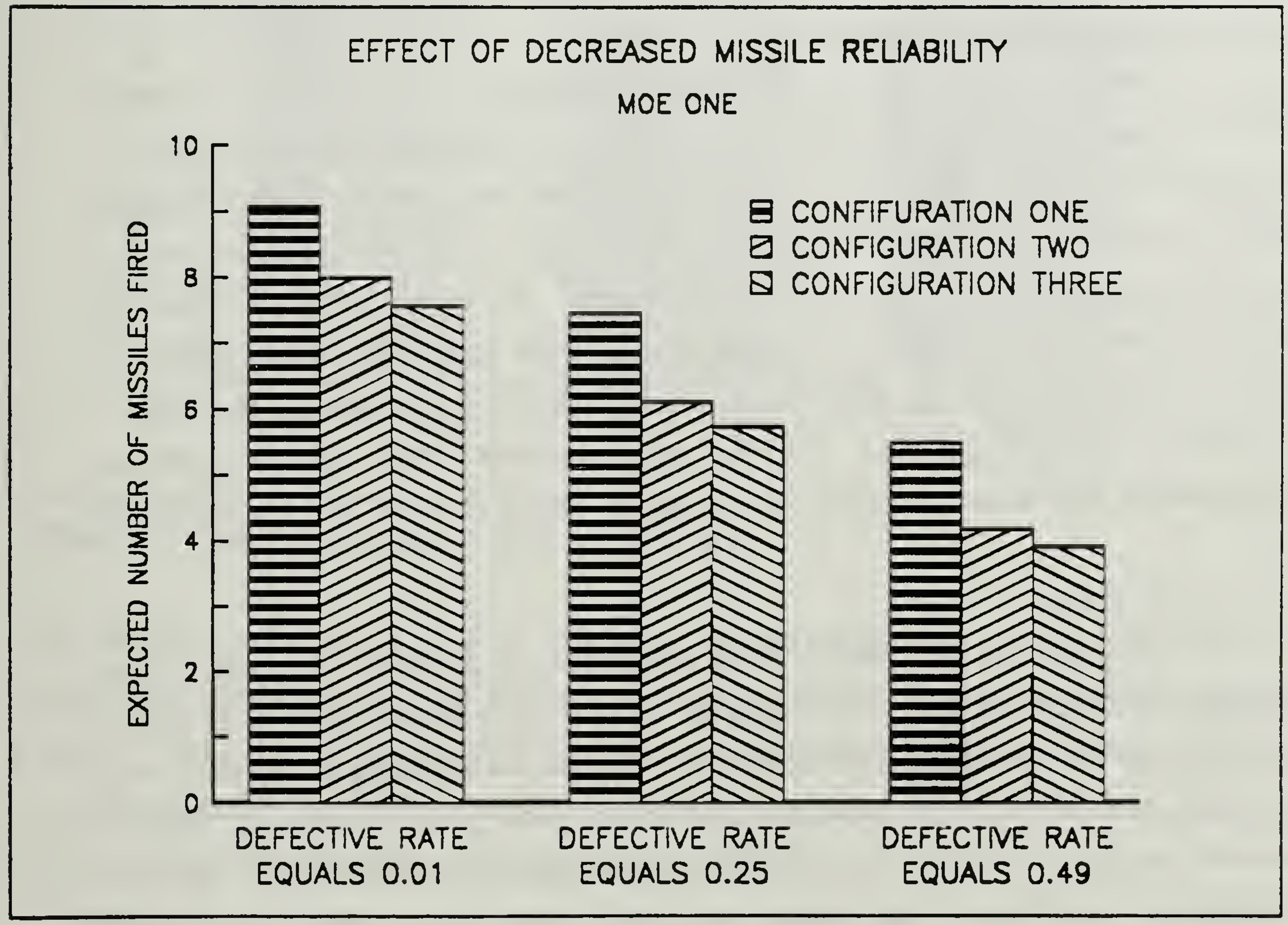

Figure 2. Analysis of Aspect One: MOE ONE

a. MOE One

When the defective missile rate is increased from 0.01 to 0.49, there are overall decreases in the expected number of missiles fired for the respective configurations of 3.58, 3.82 and 3.66. This gives the impression that there is a "standard" loss of about 3.7 missiles fired for each configuration. There was no evidence found in the

Markov chain or input data to support a generalization of a "standard" loss result across configurations.

However, it was noted that the decreases for Configurations One and Two were both 48 percent of the original expected number of missiles fired while the decrease for Configuration One was 40 percent. Inspection of the input data and the Markov chain showed this to be reasonable. Because Configurations Two and Three cause the launch platoon to leave the fire point in order to transload, a fire mission being successful had little impact upon the vulnerability to destruction. Instead, the vulnerabilities to destruction depend more on the number of trips to the transload point than on the number of successful fire missions.

Therefore, the change in the expected number of missiles fired is nearly equivalent to the rate of defective missiles. Configuration One's survivability, however, is more dependant upon the number of successful fire missions, since the launch platoon transloads a portion of the time on the fire point. After a successful fire mission the launch platoon becomes more vulnerable to destruction. If the percentage of defective missiles is increased, the proportion of transloads on a fire point after a successful fire mission decreases. Because the vulnerability has decreased, the platoon has the opportunity to attempt more fire missions. Thus the percentage decrease in number of missiles fired is somewhat less than the increase in defective missile rate (40 percent verses 49 percent).

b. MOE Two

Notice that the expected survival time for Configurations One and Three are essentially equivalent (Table 3 and Figure 2). The previous advantage Configuration Three had in longevity has diminished significantly. When transloading at the transload point (Configuration One), an increase in the defective missile rate increases the number of transloads conducted after misfires, decreasing vulnerability to destruction. The relative vulnerability elsewhere in the process, (eg., because of the increased travel time) goes up. In effect, as the reliability decreases, Configuration One spends increasingly more time traveling and transloading per missile fired.

The vulnerability assosiated with Configuration Two and Three is more dependent upon the number of transloads and trips to the transload point than the proportion of successful fire missions. As the defective missile rate increases, the change in the number of transloads before destruction is less significant for Configurations Two and Three than it is for Configuraton One. After a fire mission, a launch platoon in Configuration Two or Three must move to the transload point or battery area to trans-

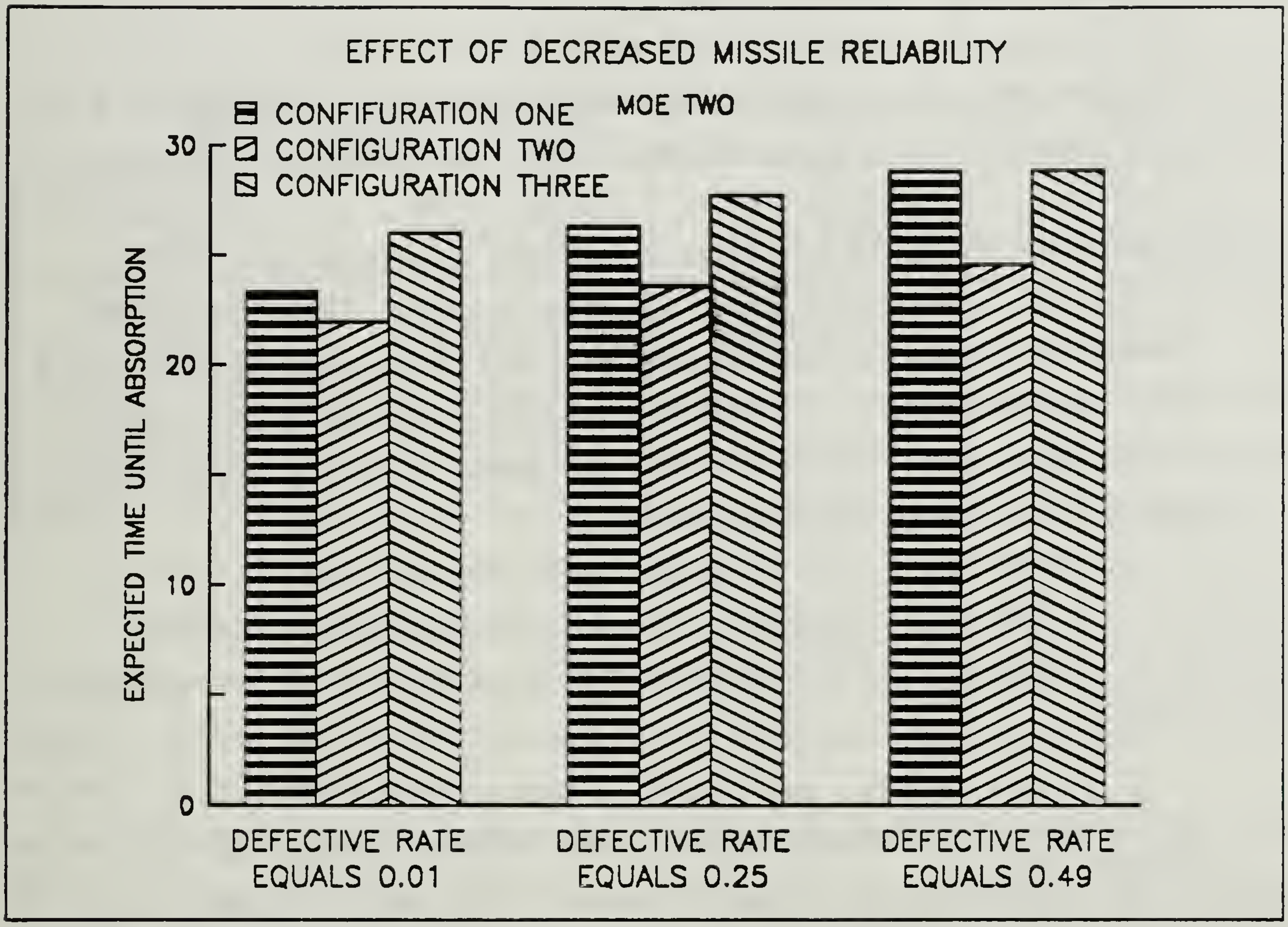

Figure 3. Analysis of Aspect One: MOE TWO

load, whether the missile is fired or defective. As the proportion of transloads due to defective missiles increases, the increase in expected survival time for Configurations Two and Three will be significantly less than for Configuration One. Notice the disparity between Configuration One's increase in expected longevity and that of the others as the missile defective rate increased from 0.01 to 0.49:

- Configuration One is expected to survive 5.51 hours longer.
- Configuration Two is expected to survive 2.62 hours longer.
- Configuration Three is expected to survive 2.84 hours longer.

These differences in increase caused the expected survival time for Configuration One to *catch up* with the expected survival time for Configuration Three. The increase in expected survival time for Configuration Two was approximately equivalent to that of Configuration Three. This left the MOE Two for Configuration Two (24.56 hours) noticably less the other configurations (Table 3).

D. ASPECT THREE: FIRE POINT USAGE

One of the decisions the commander must make is whether to send his launch platoons to fire points which are considered detected by the enemy. There may be a trade-off in work expended to keep a high number of new or undetected fire points surveyed.

Fire point usage, specifically the percentage of fire points considered detected which are used in fire missions, is the third aspect of the model examined. When the launch platoon has finished transloading (at other than the fire point), there is a probability that the next fire point selected is detected. For this evaluation the percentage of firing points which are detected was increased in order to observe the impact on the two MOEs.

1. Increasing the percentage of detected fire points

Initially the percentage of detected fire points was increased from 0.1 (from the base scenario) to 0.5. This means that after transloading, the platoon has a probability of 0.5 of going to a fire point which is considered detected. The results of this change are listed in Table 4.

Table 4. RESULTS OF INCREASING THE PERCENTAGE OF DETECTED FIRE POINTS

MEASURES OF EFFECTIVENESS	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
EXPECTED NUMBER OF ROUNDS FIRED	7.654252836	6.79038636	6.481387864
EXPECTED TIME UNTIL ABSORPTION	19.83554106	18.37516338	22.571338928

Notice the decrease in both MOEs across the configuration types. The rate of fire changed little from that of the base scenario:

- Configuration One fires one missile every 2.59 hours.
- Configuration Two fires one missile every 2.76 hours.
- Configuration Three fires one missile every 3.50 hours.

2. Further increasing the percentage of detected fire points

The percentage of detected fire points was further increased from 0.5 to 0.9. (See Table 5).

Table 5. RESULTS OF FURTHER INCREASING THE PERCENTAGE OF DETECTED FIRE POINTS

MEASURES OF EFFECTIVENESS	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
EXPECTED NUMBER OF ROUNDS FIRED	6.626345317	5.904755892	5.67751199
EXPECTED TIME UNTIL ABSORPTION	17.2731519	16.39101014	20.25643169

Both MOEs continued to decrease for all configurations and the rank orders did not change. However, comparisons of expected survival hours gained per decrease in expected missiles fired between Configurations Three and One provide an important observation, particularly when comparing Table 5 with Table 1. From Table 1 (basic scenario), the difference between the expected number of missiles fired for Configuration One and Configuration Three divided by the difference between the expected time until absorption for these two configurations gives a ratio is (2.65/1.51) = 1.76 survival hours gained per loss in expected missiles fired when choosing Configuration Three over Configuration One. The corresponding result for fewer undetected fire points (Table 5) is (2.98/0.95) = 3.13 survival hours gained per missile lost when choosing Configuration Three over One. Thus, as the number of undetected fire points is reduced, the relative advantage of Configuration Three over Configuration One with respect to expected survival time gained per missile lost is reduced. Finally, there was little affect on the rate of fire:

- Configuration One fires one missile every 2.60 hours.
- Configuration Two fires one missile every 2.78 hours.
- Configuration Three fires one missile every 3.57 hours.

3. Overview

The decreases in these MOEs, as shown in Figures 4 and 5 were large. Inspection of the Markov chain showed that the effect of changing the percentage of detected fire points depends upon the vulnerability to destruction while at a detected fire point, which is reasonable. Comparing the changes in MOEs when increasing the pro-

portion of detected fire points from 10 to 50 percent to the changes in MOEs when further increasing the percentage from 50 percent to 90 percent gave interesting results. The change in both MOEs as a result of the first increase in proportion of detected fire points was significantly greater than the change as a result of the subsequent (equal) increase in the proportion of detected fire points. This is especially apparent for MOE Two (See Tables 6 and 7).

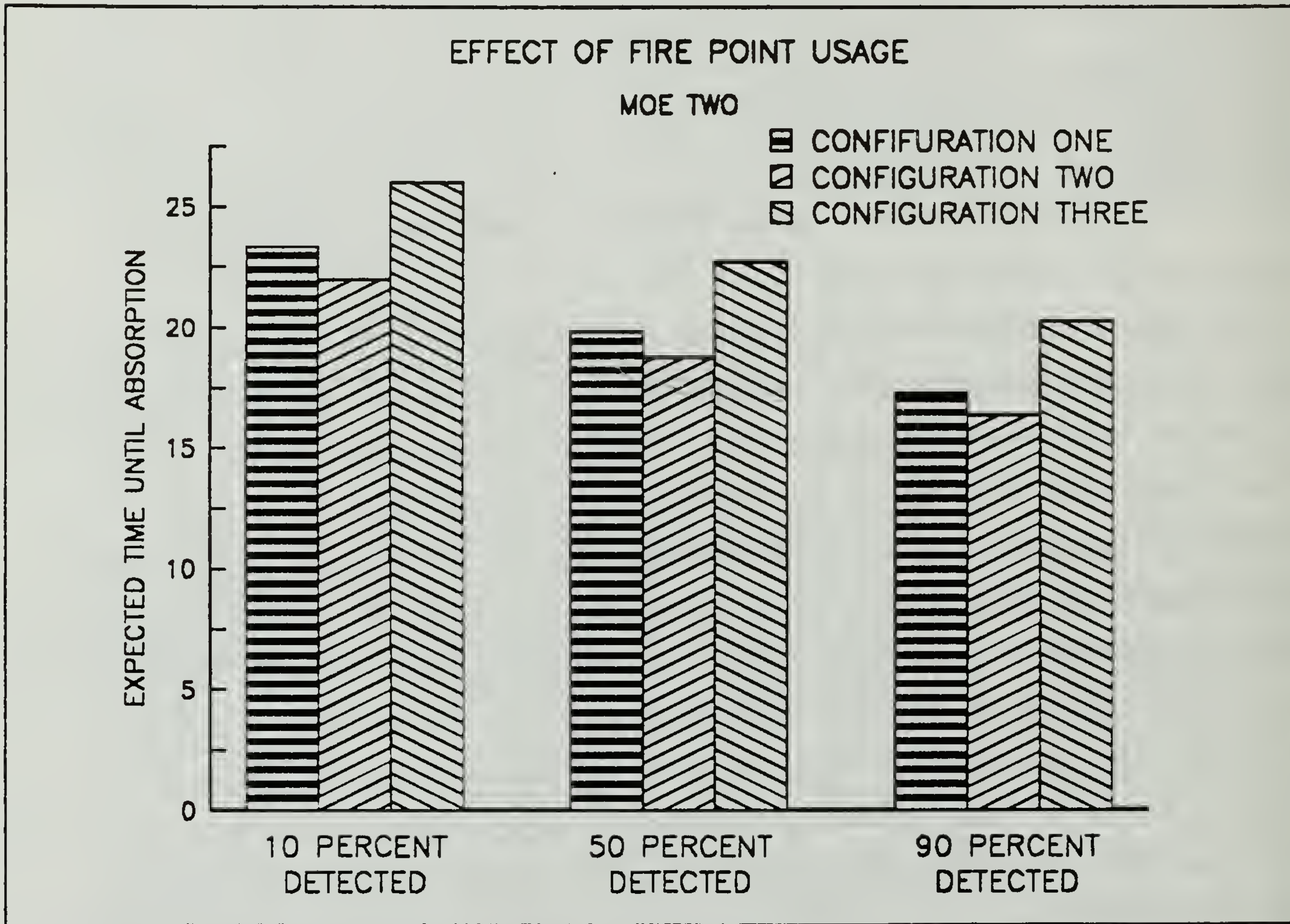

Figure 4. Analysis of Aspect Two: MOE ONE

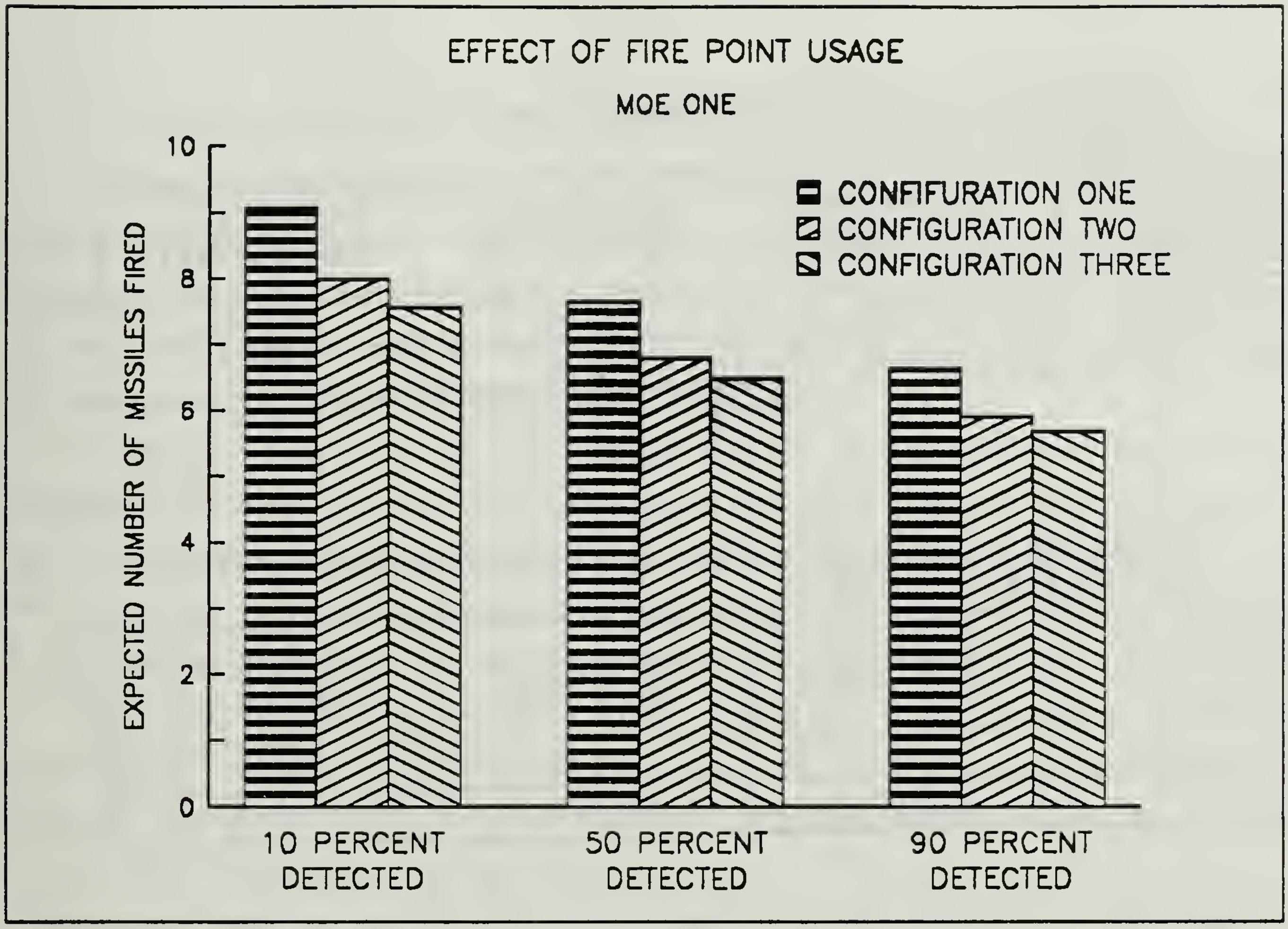

Figure 5. Analysis of Aspect Two: MOE TWO

Again a review of the Markov chain shows that as more detected fire points are used, vulnerability to destruction at the fire point increases, adversely affecting both measures of effectiveness. Notice, however, that there is a probability that a fire mission will be aborted at the detected fire point and the launcher sent to an undetected fire point (unrelated to the percentage of detected fire points) in order to preclude destruction. Therefore, as the percentage of detected fire points increases, the percentage of this type of aborted fire mission also increases. This has a slowing effect on the rate of increase in the use of detected fire points and likewise slows down the rate of decrease in vulnerability. For this reason the values of the MOEs are not linearly related to percentage of fire points detected.

Table 6. DECREASE IN MOE ONE WHEN RAISING PERCENTAGE OF DETECTED FIRE POINTS.

INCREASE IN PERCENT DETECTED	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
0.01 to 0.25	1.410	1.202	1.071
0.25 to 0.49	1.028	0.886	0.804

Table 7. DECREASE IN MOE TWO WHEN RAISING PERCENTAGE OF DETECTED FIRE POINTS.

INCREASE IN PERCENT DETECTED	CONFIGURATION ONE	CONFIGURATION TWO	CONFIGURATION THREE
0.01 to 0.25	3.500	3.195	3.274
0.25 to 0.49	2.562	2.361	2.457

4. Conclusion

This Semi-Markov model has a great advantage over large scale simulation models in its ability to make caus/effect relationships more transparent to the user. In this model, the Markov chain and the input variables can be reviewed in order to understand and explain results. It must be remembered that results and conclusions derived from this model always depend upon the input data. Varying situations give different outputs, rankings and conclusions.

VII. SUMMARY

Lance will remain as the primary land based nuclear deterant in continental Europe until at least the mid 1990s. Now, in the absence of Pershing II missiles, NATO must take special interest in Lance's abilities. Is Lance able to accomplish the mission? How efficiently will Lance be used in combat? The semi-Markov Lance model presented in this thesis is a tool designed to answer these questions.

The model proves to be sensitive to scenario input. It allows the user to input and manipulate command decisions and then observe the results. Output from the model in the form of number of rounds fired and time until absorption is tangible and easily understood. The model might be improved if the probabilty of being detroyed or being detected were a function of time spent in the state rather than a constant.

There are further uses of the Lance model. Changes in tactical doctrine can be entered as model input or the APL code can be easily altered, if necessary. Projected additions or changes in equipment configurations can be entered in the same manner to evaluate their impact upon combat effectiveness.

A semi-Markov process proved to be useful in modeling Lance and has great potential for modeling other systems. This could be a starting point for developing models of other related artillery missile systems. Much could be learned if a model were now developed for ATACMS, the replacement for Lance, while the system is being developed and tactical doctrine for the system is being written. Results from such a model could be compared with results of the Lance model to evaluate and justify the aquisition of ATACMS.

The greatest potential of this type of combat model is its ability to be incorporated into other combat models. Analytical models such as Markof chain models can quickly receive input from other models to be used to adjust their transition matrices. After evaluation, the ensuing results would be used as input by other similar models which would adjust their respective transition matrices accordingly. Such a system of models would take full advantage of the attributes of analytical models.

With changing political environments and increasing technology in our age, combat models can give an edge to military planning and preparation for future missions. It is hoped that this Lance model will be used to enhance the U.S. Army's commitment to readiness.

APPENDIX A.

Table 8. LEVEL ONE STATES CONCERNING UNDETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS TWO MISSILES.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
1	En route to an undetected fire point without a fire mission: The platoon travels from the battery position to a fire point and goes to a hide position (state 5) near the fire point.	2, 5, 92
2	Down en route to an undetected fire point without a fire mission: A vehicle has broken down and stops the platoon from traveling until it is repaired or replaced. The platoon still has no mission.	5, 92
3	En route to an undetected fire point with a fire mission: This is same as State 1 except in this state the launch platoon has received a fire mission and goes straight to the fire point (state 6).	4, 6, 92
4	Down en route to undetected fire point with a mission: Same as State 2 except the platoon has received a fire mission. If the mission is aborted because of the break down the platoon will go to a hide position near the fire point (state 5).	5, 6, 92
5	In hide position at an undetected fire point: The platoon is near an undetected fire point, camouflaged and waiting for a fire mission. When the mission comes the platoon goes to the fire point (state 6). If the platoon becomes detected while waiting it transitions to state 14.	6, 14
6	On an undetected fire point with a mission laying: The platoon has a fire mission and is on an undetected fire point laying the missile. The platoon may receive orders to fire "At My Command" (state 7). If not the platoon will either fire successfully (state 19) or misfire (state 8).	7, 8, 19
7	On an undetected fire point laid awaiting fire command: The platoon is on an undetected fire point with all firing procedures completed but has been given the order to fire "At My Command." When the command to fire is received the platoon fires (state 19) or misfires (state 8). There is a probability that the platoon becomes detected (state 16).	8, 16, 19

Table 9. LEVEL ONE STATES CONCERNING UNDETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS TWO (CONTINUED).

STATE	STATE DESCRIPTION	TRANSITIONS TO:
8	Misfire on an unused fire point: The platoon attempted to fire the missile but received a NO-GO in launch procedures. The platoon conducts misfire procedures, checks out the missile and again attempts to fire the missile. If the missile fires then the platoon transitions to state 19. If the missile is defective then, depending upon the tactical configuration, the platoon either transloads another missile onto the launcher at the fire point (state 22) or travels to the transload point to receive another missile (state 31).	19, 22, 31

Table 10. LEVEL ONE STATES CONCERNING DETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS TWO MISSILES.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
9	En route to detected fire point without a fire mission: The launch platoon is en route from the battery position to a fire point which is assumed to be detected by the enemy. Because it has no mission the platoon will go to a hide position (state 13)	10, 13, 92
10	Down en route to a detected fire point without a fire mission: The platoon has a vehicular break down while en route to a detected fire point.	13, 92
11	En route to detected fire point with a mission: This is same as State 9 except the platoon has received a fire mission and goes straight to the fire point.	12, 15, 92
12	Down en route to a detected fire point with a mission: This is same as State 10 except the platoon has received a fire mission. If the fire mission is aborted because of the breakdown, the platoon goes to a hide position (state 13).	13, 15, 92

Table 11. LEVEL ONE STATES CONCERNING DETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS TWO MISSILES (CONT)

STATE	STATE DESCRIPTION	TRANSITIONS TO:
13	In the hide position waiting for a mission at a detected fire point: The launch platoon is hiding in the vicinity of a detected fire point camouflaged and waiting for a fire mission. The platoon itself is not detected but may become detected (state 14).	14, 15
14	Detected in hide position waiting for mission: The platoon is hiding near a detected fire point camouflaged and waiting for a fire mission but has also become detected.	15, 93
15	On a detected fire point with a fire mission laying: The platoon has a fire mission and is on a detected fire point laying the missile. The platoon may might shoot (state 19), misfire (state 18), or receive the order "At My Command" (state 16).	16, 18, 19, 93
16	Laid awaiting fire command on a detected point: Launch platoon is on a detected fire point with firing procedures completed but has been given the order to fire "At My Command". The platoon may be ordered to abort the mission (state 17) Otherwise the platoon will fire (state 19) or misfire (state 18).	17, 18, 19, 93
17	Abort present mission and go to an undetected point: The platoon, which is ready to fire and waiting for the command to fire, has been ordered to abort the present fire mission and move to an undetected fire point to avoid enemy attack.	2, 5, 93
18	Misfire on a detected point:. The platoon attempted to fire but received a NO-GO. They conduct misfire procedures, check out the missile and again attempt ot fire the missile. If the missile fires the platoon transitions to state 19. If the missile is defective the platoon may transload another missile onto the launcher at the point (state 21). The platoon may also travel to the transload point to receive another missile (state 31) a fire point, or transload en route to another fire point (states 23, 25).	19, 21, 23, 25, 31, 93
19	Missile shot: The platoon fired the missile and now conducts post fire operations and prepares to transload on the fire point (state 20), transload en route to another fire point (states 23, 25, 27, 29), or travel to the transload point(state 31). The ammunition status has changed. Therefore, after transloading the launch platoon will begin operating in Level Two states. Because of the signature of the missile when fired, the fire point is now considered detected.	20, 23, 25, 27, 29, 31, 93

Table 12. LEVEL ONE STATES CONCERNING TRANSLOAD OPERATIONS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS TWO MISSILES.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
20	Transloading at a detected fire point (after a mission): After a fire mission the platoon transloads another round onto the launcher. Because the platoon has only two rounds, it transitions to states in level two. The platoon will either hide (state 47) or go straight to the fire point (state 48).	47, 48, 93
21	Transloading at a detected fire point after a misfire: After determining that a missile is defective, the platoon transloads another round onto the launcher and remains at the detected fire point to either hide (state 46) or to conduct another fire mission (state 48).	46, 48, 93
22	Transloading at the same undetected fire point after a misfire: After a misfire and determination that the missile is defective, the platoon transloads another round onto the launch while remaining at the same undetected fire point to either hide (state 38) or to conduct another fire mission (state 39). If the launch platoon becomes detected while transloading, the platoon will be hiding but be detected (state 47) or it conducts the mission on the (now) detected point (state 48).	38, 39, 47, 48, 93
23	Transloading en route to an undetected fire point without a mission: After a fire mission or misfire on a detected fire point the platoon leaves and transloads en route to an undetected fire point. Because there is no mission, the platoon will go to a hide position (state 38).	24, 38, 93
24	Down transloading en route to an undetected fire point without a mission: A vehicle breaks down while transloading en route.	38, 89
25	Transloading en route to an undetected fire point with a mission: Identical to state 23 except the platoon has a fire mission and will go to the fire point (state 38).	26, 39, 89
26	Down transloading en route to an undetected fire point with a mission: Identical to state 24 except the platoon has a fire mission.	39, 89
27	Transloading en route to a detected fire point without a mission: After a fire mission or misfire on a detected fire point the platoon leaves and transloads en route to a detected fire point. Because there is no mission, the platoon will go to the hide position (state 46).	28, 46, 89

Table 13. LEVEL ONE STATES CONCERNING TRANSLOAD OPERATIONS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS TWO MISSILES.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
28	Down transloading en route to a detected fire point without a mission: A vehicle breaks down while transloading en route.	46, 89
29	Transloading en route to a detected fire point with a mission: Identical to state 27 except the platoon has a fire mission and goes to the fire point (state 48).	48, 30, 89
30	Down transloading en route to a detected fire point with a mission: Identical to state 28 except the platoon has a fire mission.	48, 89
31	En route to the local transload point: The launch platoon must return to and transload at the local transload point (state 33) where the Loader-Transporter is located during fire missions.	32, 33, 90
32	Down en route to local transload point: A vehicle breaks down while en route to the local transload point.	33, 90
33	Transloading at local transload point: Platoon receives a missile at the local transload point and goes either to an undetected fire point (state 34 or 36) or to a detected fire point (state 42 or 44).	34, 36, 42, 44, 93

APPENDIX B.

Table 14. LEVEL TWO STATES CONCERNING UNDETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS ONE MISSILE.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
34	En route to new fire point without a fire mission: The platoon travels from the battery position to a fire point and goes to a hide position (state 38) near the fire point.	35, 38, 92
35	Down en route to new fire point without a fire mission: A vehicle has broken down and stops the platoon from traveling until it is repaired or replaced. The platoon still has no mission.	38, 92
36	En route to new fire point with a fire mission: This is same as State 34 except in this state the launch platoon has received a fire mission and goes straight to the fire point (state 39).	37, 39, 92
37	Down en route to new fire point with a mission: Same as State 35 except the platoon has received a fire mission. If the mission is aborted because of the break down the platoon will go to a hide position near the fire point (state 38).	38, 39, 92
38	In hide position at an undetected fire point: The platoon is near an undetected fire point, camouflaged and waiting for a fire mission. When the mission comes the platoon goes to the fire point (state 39). If the platoon becomes detected while waiting it transitions to state 14.	39, 47
39	On new fire point with a mission laying: The platoon has a fire mission and is on an undetected fire point laying the missile. The platoon may receive orders to fire "At My Command" (state 40). If not the platoon will either fire successfully (state 52) or misfire (state 41).	40, 41, 52
40	On new fire point laid awaiting fire command: The platoon is on an undetected fire point with all firing procedures completed but has been given the order to fire "At My Command." When the command to fire is received the platoon fires (state 52) or misfires (state 41). There is a probability that the platoon becomes detected (state 49).	41, 49, 52

Table 15. LEVEL TWO STATES CONCERNING UNDETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS ONE (CONTINUED).

STATE	STATE DESCRIPTION	TRAN-SITIONS TO:
41	Misfire on an unused fire point: The platoon attempted to fire the missile but received a NO-GO in launch procedures. The platoon conducts misfire procedures, checks out the missile and again attempts to fire the missile. If the missile fires then the platoon transitions to state 52. If the missile is defective then, depending upon the tactical configuration, the platoon either transloads another missile onto the launcher at the fire point (state 55) or travels to the transload point to receive another missile (state 64).	52, 55, 64

Table 16. LEVEL TWO STATES CONCERNING DETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS ONE MISSILE.

STATE	STATE DESCRIPTION	TRAN-SITIONS TO:
42	En route to detected fire point without a fire mission: The launch platoon is en route from the battery position to a fire point which is assumed to be detected by the enemy. Because it has no mission the platoon will go to a hide position (state 46)	43, 46, 92
43	Down en route to a detected fire point without a fire mission: The platoon has a vehicular break down while en route to a detected fire point.	46, 92
44	En route to detected fire point with a mission: This is same as State 42 except the platoon has received a fire mission and goes straight to the fire point (state 48).	45, 48, 92
45	Down en route to a detected fire point with a mission: This is same as State 43 except the platoon has received a fire mission. If the fire mission is aborted because of the breakdown, the platoon goes to a hide position (state 46).	46, 48, 92

Table 17. LEVEL TWO STATES CONCERNING DETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS ONE MISSILE (CONT)

STATE	STATE DESCRIPTION	TRANSITIONS TO:
46	In the hide position waiting for a mission at a detected fire point: The launch platoon is hiding in the vicinity of a detected fire point camouflaged and waiting for a fire mission. The platoon itself is not detected but may become detected (state 47).	47, 48
47	Detected in hide position waiting for mission: The platoon is hiding near a detected fire point camouflaged and waiting for a fire mission but has also become detected.	48, 93
48	On a detected fire point with a fire mission laying: The platoon has a fire mission and is on a detected fire point laying the missile. The platoon may might shoot (state 52), misfire (state 51), or receive the order "At My Command" (state 49).	49, 51, 52, 93
49	Laid awaiting fire command on a detected point: Launch platoon is on a detected fire point with firing procedures completed but has been given the order to fire "At My Command". The platoon may be ordered to abort the mission (state 50) Otherwise the platoon will fire (state 52) or misfire (state 51).	50, 51, 52, 93
50	Abort present mission and go to an undetected point: The platoon, which is ready to fire and waiting for the command to fire, has been ordered to abort the present fire mission and move to an undetected fire point to avoid enemy attack.	35, 38, 93
51	Misfire on a detected point:. The platoon attempted to fire but received a NO-GO. They conduct misfire procedures, check out the missile and again attempt ot fire the missile. If the missile fires the platoon transitions to state 52. If the missile is defective the platoon may transload another missile onto the launcher at the point (state 54). The platoon may also travel to the transload point to receive another missile (state 64) a fire point, or transload en route to another fire point (states 56, 58).	52, 54, 56, 58, 64, 93
52	Missile shot: The platoon fired the missile and now conducts post fire operations and prepares to transload on the fire point (state 53), transload en route to another fire point (states 56, 58, 60, 63), or travel to the transload point(state 64). The ammunition status has changed. Therefore, after transloading the launch platoon will begin operating in Level Three states. Because of the signature of the missile when fired, the fire point is now considered detected.	53, 56, 58, 60, 62, 64, 93

Table 18. LEVEL TWO STATES CONCERNING TRANSLOAD OPERATIONS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS ONE MISSILE.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
53	Transloading at a detected fire point (after a mission): After a fire mission the platoon transloads another round onto the launcher. Because the platoon has only two rounds, it transitions to states in level two. The platoon will either hide (state 80) or go straight to the fire point (state 81).	80, 81, 93
54	Transloading at a detected fire point after a misfire: After determining that a missile is defective, the platoon transloads another round onto the launcher and remains at the detected fire point to either hide (state 79) or to conduct another fire mission (state 81).	79, 81, 93
55	Transloading at the same undetected fire point after a misfire: After a misfire and determination that the missile is defective, the platoon transloads another round onto the launch while remaining at the same undetected fire point to either hide (state 71) or to conduct another fire mission (state 72). If the launch platoon becomes detected while transloading, the platoon will be hiding but be detected (state 80) or it conducts the mission on the (now) detected point (state 81).	71, 72, 80, 81, 93
56	Transloading en route to an undetected fire point without a mission: After a fire mission or misfire on a detected fire point the platoon leaves and transloads en route to an undetected fire point. Because there is no mission, the platoon will go to a hide position (state 71).	57, 71, 93
57	Down transloading en route to new fire point without a mission: A vehicle breaks down while transloading en route.	71, 89
58	Transloading en route to new fire point with a mission: Identical to state 56 except the platoon has a fire mission and will go to the fire point (state 72).	59, 72, 89
59	Down transloading en route to new point with a mission: Identical to state 57 except the platoon has a fire mission.	72, 89
60	Transloading en route to a detected fire point without a mission: After a fire mission or misfire on a detected fire point the platoon leaves and transloads en route to a detected fire point. Because there is no mission, the platoon will go to the hide position (state 79).	61, 79, 89

Table 19. LEVEL TWO STATES CONCERNING TRANSLOAD OPERATIONS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS ONE MISSILE. (CONT)

STATE	STATE DESCRIPTION	TRANSITIONS TO:
61	Down transloading en route to a detected fire point without a mission: A vehicle breaks down while transloading en route.	79, 89
62	Transloading en route to a detected fire point with a mission: Identical to state 60 except the platoon has a fire mission and goes to the fire point (state 81).	63, 81, 89
63	Down transloading en route to a detected fire point with a mission: Identical to state 61 except the platoon has a fire mission.	81, 89
64	En route to the local transload point: The launch platoon must return to and transload at the local transload point (state 66) where the Loader-Transporter is located during fire missions.	65, 66, 90
65	Down en route to local transload point: A vehicle breaks down while en route to the local transload point.	66, 90
66	Transloading at local transload point: Platoon receives a missile at the local transload point and goes either to an undetected fire point (state 67 or 69) or to a detected fire point (state 75 or 77).	67, 69, 75, 77, 93

APPENDIX C.

Table 20. LEVEL THREE STATES CONCERNING UNDETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER NONE.

STATE	STATE DESCRIPTION	TRAN-SITIONS TO:
67	En route to new fire point without a fire mission: The platoon travels from the battery position to a fire point and goes to a hide position (state 71) near the fire point.	68, 71, 92
68	Down en route to new fire point without a fire mission: A vehicle has broken down and stops the platoon from traveling until it is repaired or replaced. The platoon still has no mission.	71, 92
69	En route to new fire point with a fire mission: This is same as State 67 except in this state the launch platoon has received a fire mission and goes straight to the fire point (state 72).	70, 72, 92
70	Down en route to new fire point with a mission: Same as State 69 except the platoon has received a fire mission. If the mission is aborted because of the break down the platoon will go to a hide position near the fire point (state 71).	71, 72, 92
71	In hide position at an undetected fire point: The platoon is near an undetected fire point, camouflaged and waiting for a fire mission. When the mission comes the platoon goes to the fire point (state 72). If the platoon becomes detected while waiting it transitions to state 14.	72, 80
72	On new fire point with a mission laying: The platoon has a fire mission and is on an undetected fire point laying the missile. The platoon may receive orders to fire "At My Command" (state 73). If not the platoon will either fire successfully (state 85) or misfire (state 74).	73, 74, 85
73	On new fire point laid awaiting fire command: The platoon is on an undetected fire point with all firing procedures completed but has been given the order to fire "At My Command." When the command to fire is received the platoon fires (state 85) or misfires (state 74). There is a probability that the platoon becomes detected (state 82).	74, 82, 85

Table 21. LEVEL THREE STATES CONCERNING UNDETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER NONE (CONTINUED).

STATE	STATE DESCRIPTION	TRANSITIONS TO:
74	Misfire on an unused fire point: The platoon attempted to fire the missile but received a NO-GO in launch procedures. The platoon conducts misfire procedures, checks out the missile and again attempts to fire the missile. If the missile fires then the platoon transitions to state 85. If the missile is defective, then the platoon travels to the transload point to receive another missile (state 86).	85, 86

Table 22. LEVEL THREE STATES CONCERNING DETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS NONE.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
75	En route to detected fire point without a fire mission: The launch platoon is en route from the battery position to a fire point which is assumed to be detected by the enemy. Because it has no mission the platoon will go to a hide position (state 79)	76, 79, 92
76	Down en route to a detected fire point without a fire mission: The platoon has a vehicular break down while en route to a detected fire point.	79, 92
77	En route to detected fire point with a mission: This is same as State 75 except the platoon has received a fire mission and goes straight to the fire point (state 81).	78, 81, 92
78	Down en route to a detected fire point with a mission: This is same as State 76 except the platoon has received a fire mission. If the fire mission is aborted because of the breakdown, the platoon goes to a hide position (state 81).	79, 81, 92

Table 23. LEVEL THREE STATES CONCERNING DETECTED FIRE POINTS: LAUNCHER HAS ONE MISSILE AND LOADER-TRANSPORTER HAS NONE (CONT).

STATE	STATE DESCRIPTION	TRANSITIONS TO:
79	In the hide position waiting for a mission at a detected fire point: The launch platoon is hiding in the vicinity of a detected fire point camouflaged and waiting for a fire mission. The platoon itself is not detected but may become detected (state 80).	80, 81
80	Detected in hide position waiting for mission: The platoon is hiding near a detected fire point camouflaged and waiting for a fire mission but has also become detected.	81, 93
81	On a detected fire point with a fire mission laying: The platoon has a fire mission and is on a detected fire point laying the missile. The platoon may might shoot (state 85), misfire (state 84), or receive the order "At My Command" (state 82).	82, 84, 85, 93
82	Laid awaiting fire command on a detected point: Launch platoon is on a detected fire point with firing procedures completed but has been given the order to fire "At My Command". The platoon may be ordered to abort the mission (state 83) Otherwise the platoon will fire (state 85) or misfire (state 84).	83, 84, 85, 93
83	Abort present mission and go to an undetected point: The platoon, which is ready to fire and waiting for the command to fire, has been ordered to abort the present fire mission and move to an undetected fire point to avoid enemy attack.	68, 71, 93
84	Misfire on a detected point:. The platoon attempted to fire but received a NO-GO. They conduct misfire procedures, check out the missile and again attempt ot fire the missile. If the missile fires the platoon transitions to state 85. If the missile is defective the platoon travels to the battery area to receive another missile (state 86).	85, 86, 93
85	Missile shot: The platoon fired the missile and now conducts post fire operations and prepares to displace. The platoon now travels to the battery area because has no missiles (regardless of tactical configuration.	86, 93

Table 24. LEVEL THREE STATES CONCERNING TRANSLOAD OPERATIONS: LAUNCER HAS NO MISSILE. LAUNCHER, IF PRESENT, HAS NONE.

STATE	STATE DESCRIPTION	TRANSITIONS TO:
86	En route to the Battery Area: The launch platoon must return to the battery area to receive more missiles. Upon arrival the platoon will receive missiles (state 88).	87, 88, 90
87	Down en route to battery area: A vehicle breaks down while en route to the Battery area.	88, 90
88	Transloading at Battery Area. Launch platoon receives a missile on the launcher and the accopanying Loader-Transporter, if in tactical configuration one or two, receives two missiles. If the platoon is in tactical configuration one or two, the platoon will travel to a fire point and transition to states in first level of activity (states 1, 3, 9, 11). If the platoon is in tactical configuration three the platoon will travel to a fire point and transition to level three states (states 67, 69, 75, 77).	1, 3, 9, 11, 67, 69, 75, 77, 91

APPENDIX D.

Table 25. ABSORPTION STATES

STATE	STATE DESCRIPTION	TRANSITIONS TO:
89	Destroyed while transloading en route. The platoon has been attacked while transloading en route and is destroyed, captured or out of action.	89
90	Destroyed en route to Transload point. Platoon is attacked while traveling to a local transload point or the battery position point and destroyed, captured or out of action for the the battle.	90
91	Destroyed at Transload point. Platoon is attacked while transloading at the local transload point or battery position and is destroyed, captured or out of action for the battle.	91
92	Destroyed en route to Fire Point.The platoon is attacked while traveling to a fire point and is destroyed, captured or rendered out of action.	92
93	Destroyed at Fire Point or hide position. The launch platoon has been attacked while hiding or operating at a fire point and is destroyed, captured or rendered out of action.	93

APPENDIX E.

Table 26. PROGVAR INPUT

IN-PUT	INPUT DESCRIPTION	VALUE
1	PROBABILITY BEING DESTROYED WHILE EN ROUTE TO A FIRE POINT FROM THE TRANSLOAD POINT	0.025
2	PROBABILITY OF VEHICULAR BREAK DOWN WHILE EN ROUTE TO A FIRE POINT FROM THE TRANSLOAD POINT	0.05
3	PROBABILITY OF BEING DESTROYED DURING BREAK DOWN WHILE ENROUTE TO A FIRE POINT FROM THE TRANSLOAD POINT	0.02
4	PROBABILITY OF A MISSION BEING ABORTED DUE TO A VEHICULAR BREAK DOWN WHILE EN ROUTE TO A FIRE POINT FROM THE TRANSOAD POINT OR BATTERY POSITION	0.05
5	PROBABILITY OF BEING DETECTED WHILE IN HIDE POSITION AT AN UNDETECTED FIRE POINT BEFORE A FIRE MISSION IS RECEIVED.	0.05
6	PROBABILITY OF BEING GIVEN FIRE AT 'MY COMMAND' VS 'WHEN READY' WHEN FIRING A MISSION FROM AN UNDETECTED FIRE POINT	0.5
7	PROBABILITY OF BEING DETECTED WHEN THE LAUNCH PLATOON HAS LAID THE MISSILE BUT IS WAITING FOR THE COMMAND TO FIRE	0.1
9	PROBABILITY OF BEING DETECTED IN THE HIDE POSITION AT A DETECTED FIRE POINT BEFORE RECEIVING A MISSION.	0.1
10	PROBABILITY OF BEING DESTROYED IN A DETECTED HIDE POSITION AT A DETECTED FIRE POINT BEFORE RECEIVING A MISSION.	0.1
11	PROBABILITY OF BEING DESTROYED WHILE LAYING THE MISSILE ON A DETECTED FIRE POINT.	0.05
12	PROBABILITY OF BEING GIVEN FIRE 'AT MY COMMAND' VS 'WHEN READY' WHEN FIRING A MISSION FROM A DETECTED FIRE POINT	0.2

Table 27. PROGVAR INPUT (CONTINUED)

INPUT	INPUT DESCRIPTION	VALUE
13	PROBABILITY OF BEING DESTROYED WHILE AWAITING COMMAND TO FIRE WHEN FIRING A MISSION FROM A DETECTED FIRE POINT	0.05
14	PROBABILITY OF RECEIVING COMMAND TO FIRE VERSES ABORT MISSION BEFORE BEING DESTROYED WHEN FIRING FROM A DETECTED FIRE POINT	0.05
15	PROBABILITY OF BEING DESTROYED WHILE ENROUTE TO A NEW POINT AFTER ABORTING A MISSION AT A DETECTED FIRE POINT.	0.02
16	PROBABILITY OF VEHICULAR BREAK DOWN WHILE ENROUTE FROM ONE FIRE POINT TO ANOTHER.	0.03
17	PROBABILITY OF BEING DESTROYED BEFORE TAKING ACTION TO REPLACE DEFECTIVE ROUND AFTER MISFIRE AT AN UNDETECTED FIRE POINT.	0.01
18	PROBABILITY OF TRANSLOADING A DEFECTIVE ROUND AFTER MISFIRE AT A DETECTED POINT AND REMAINING AT THE POINT FOR THE NEXT MISSION VERSES TRANSLOADING THE ROUND WHILE EN ROUTE TO ANOTHER FIRE POINT.	0.1
20	PROBABILITY OF ABORTING MISSION BECAUSE OF DEFECTIVE MISSILE ON A DETECTED FIRE POINT (DO NOT TRANSLOAD AND CONTINUE WITH THE SAME FIRE MISSION.	0.6
21	PROBABILITY OF BEING DESTROYED WHILE RECOVERING OR DISPLACING AFTER A SUCCESSFUL FIRE MISSION	0.03
22	PROBABILITY TRANSLOADING AND FIRING AGAIN AT THE SAME FIRE POINT VERSES TRANSLOADING EN ROUTE TO ANOTHER POINT.	0.1
24	PROBABILITY OF RECEIVING A MISSION WHILE TRANSLOADING ENROUTE TO A FIRE POINT	0.5
25	PROBABILITY OF BEING DESTROYED WHILE TRANSLOADING AT THE FIRE POINT AFTER A FIRE MISSION	0.15
26	PROBABILITY OF RECEIVING A MISSION WHILE TRANSLOADING AT THE FIRE POINT AFTER A SUCCESSFUL FIRE MISSION	0.5

Table 28. PROGVAR INPUT (CONTINUED)

IN-PUT	INPUT DESCRIPTION	VALUE
27	PROBABILITY OF BEING DESTROYED WHILE TRANS-LOADING AT DETECTED POINT AFTER A MISFIRE	0.09
28	PROBABILITY OF TRANSLOADING AT THE SAME DE-TECTED FIRE POINT AFTER A MISFIRE AND CONTIN-UING THE FIRE MISSION VERSES TRANSLOADING AT THE POINT, ABORTING THE MISSION AND GOING TO THE HIDE POSITION FOR THAT FIRE POINT.	0.3
29	PROBABILITY OF BEING DESTROYED WHILE TRANS-LOADING AT AN UNDETECTED FIRE POINT AFTER A MISFIRE	0.03
30	PROBABILITY OF BEING DETECTED WHILE TRANS-LOADING AT A NEW FIRE POINT AFTER A MISFIRE	0.1
31	PROBABILITY OF ABORTING MISSION BECAUSE OF A MISFIRE ON A NEW POINT AND MOVING TO THE HIDE POSITION AT THAT POINT	0.2
32	PROBABILITY OF BEING DESTROYED WHILE TRANS-LOADING EN ROUTE FROM A DETECTED FIRE POINT TO A NEW OR UNDETECTED FIRE POINT.	0.04
34	PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN, TRANSLOADING EN ROUTE TO A NEW FIRE POINT	0.02
35	PROBABILITY OF DESTRUCTION WHILE TRANSLOAD-ING EN ROUTE TO A DETECTED FIRE POINT.	0.04
37	PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN, TRANSLOADING EN ROUTE TO A DETECTED FIRE POINT	0.01
38	PROBABILITY OF BEING DESTROYED WHILE EN ROUTE FROM A FIRE POINT TO THE LOCAL TRANS-LOAD POINT	0.025
39	PROBABILITY OF VEHICULAR BREAK DOWN WHILE EN ROUTE TO THE LOCAL TRANSLOAD POINT	0.09
40	PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN WHILE ENROUTE TO THE LOCAL TRANSLOAD POINT	0.06
41	PROBABILITY OF BEING DESTROYED WHILE AT LOCAL TRANSLOAD POINT	0.05

Table 29. PROGVAR INPUT (CONTINUED)

IN-PUT	INPUT DESCRIPTION	VALUE
42	PROBABILITY OF RECEIVING A FIRE MISSION PRIOR TO ARRIVING AT THE FIRE POINT AFTER TRANSLOADING(BATTERY OR LOCAL TRANSLOAD POINT)	0.7
43	PROBABILITY MISSILES ARE ALREADY SUPPLIED AT BATTERY VERSES REQUIRING THE LAUNCH PLATOON TO WAIT FOR MISSILES TO ARRIVE.	0.8
45	PROBABILITY OF A MISFIRE ON FIRST ATTEMPT TO FIRE A MISSILE	0.1
46	PROBABILITY OF SUCCESSFULLY FIRING THE MISSILE WHICH FORMERLY MISFIRED BUT WAS SERVICABLE. (UNEXPLAINED NO-GO)	0.9
47	PROBABILITY THAT A FIRING POINT IS UNUSED AND UNDETECTED VERSES USED (FIRED FROM, ASSUMED TO BE DETECTED) ENTER CONFIGURATION (1, 2 OR 3)	0.9
50	PROBABILITY OF BEING DESTROYED WHILE EN ROUTE FROM A FIRE POINT TO THE BATTERY AREA FOR TRANSLOAD OPERATIONS	0.05
51	PROBABILITY OF VEHICULAR BREAK DOWN WHILE EN ROUTE TO BATTERY AREA FOR TRANSLOAD OPERATIONS	0.11
52	PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN WHILE ENROUTE TO BATTERY AREA FOR TRANSLOAD OPERATIONS	0.08
53	PROBABILITY OF BEING DESTROYED WHILE AT THE BATTERY AREA	0.01

APPENDIX F.

Table 30. PROGTIME INPUTS

IN-PUT	INPUT DESCRIPTION	VALUE
1	TRAVEL TIME BETWEEN LOCAL TRANSLOAD POINT TO A FIRE POINT	20
2	TRAVEL TIME FROM BATTERY POSITION TO A FIRE POINT	40
3	EXPECTED TIME NEEDED TO RECOVER WHEN DOWN FOR MAINTENANCE EN ROUTE	60
4	TIME WAITING IN HIDE POSITION UNTIL MISSION RE-CEIVED	60
5	TIME TO TRAVEL FROM HIDE POSITION TO THE FIRE POINT AND LAY WEAPON	30
6	TIME UNTIL RECEIVING COMMAND TO FIRE WHEN LAID AND WAITING	30
7	TIME NEEDED TO CONDUCT MISFIRE PROCEDURES AND FIRE AGAIN	30
8	TIME NEEDED TO CONDUCT MISFIRE PROCEDURES AND REJECT BAD ROUND	20
9	TIME UNTIL RECEIVING COMMAND TO ABORT MISSION WHEN LAID AND DETECTED	40
10	TIME TO DISPLACE WHEN ABORTING MISSION	15

Table 31. PROGTIME INPUTS (CONTINUED)

INPUT	INPUT DESCRIPTION	VALUE
11	TIME TO DISPLACE AFTER ROUND IS FIRED	15
12	TIME NEEDED TO TRANSLOAD AT A FIRE POINT AFTER A MISSION IS SHOT	20
13	TIME NEEDED TO TRANSLOAD AT A FIRE POINT AFTER A MISFIRE (CON 1)	30
14	TIME NEEDED TO TRANSLOAD EN ROUTE AND TRAVEL TO NEXT POINT (CON 1)	50
15	EXPECTED TIME TO TRANSLOAD AT TRANSLOAD POINT OR BATTERY POSITION	30
17	TIME UNTIL BECOMING DETECTED WHILE IN HIDE POSITION (UNDETECTED POINT)	120
18	TIME UNTIL BECOMING DETECTED WHILE IN HIDE POSITION(DETECTED POINT)	80
19	ADDITIONAL TIME IN DETECTED HIDE POSITION BEFORE MISSION RECEIVED	30
20	TIME UNTIL BECOMING DETECTED WHILE LAID WAITING FOR A COMMAND TO FIRE ON AN UNDETECTED FIRE POINT	40

APPENDIX G.

```
 ∇ PROGVAR
⍝THIS PROGRAM ASKS THE PROGRAMMER TO ENTER A SERIES OF PROBABILITIES
⍝WHICH ARE USED IN THE PROGRAMS PROG1MTX, PROG2MTX AND PROG3MTX TO
⍝CREATE THE 93 BY 93 TRANSITION MATRIX (PIJM)
⍝FIRST CREATE A VECTOR (VAR) TO STORE THE INPUT VARIABLES
 VAR←53⍴0
⍝NOW THE PROGRAMMER ENTERS THE INITIAL CONFIGURATION
⍝THE PROGRAMMER DOES NO RUN THIS ENTIRE PROGRAM IN ORDER TO CHANGE
⍝ THE CONFIGURATION BUT CAN USE PROGRAM 'CON'
 ''
 'ENTER CONFIGURATION (1, 2 OR 3)'
 VAR[49]←⎕
⍝CONFIGURATION 1
 →(VAR[49]≠1)⍴LOOP1
 VAR[(8,19,23,48)]←1
 →LOOP3
LOOP1: ⍝CONFIGURATION 2
 →(VAR[49]≠2)⍴LOOP2
 VAR[(8,19,23)]←0
 VAR[48]←1
 →LOOP3
LOOP2: ⍝CONFIGURATION 3
 VAR[(8,19,23,48)]←0
 ''
LOOP3: ⍝NOW THE PROGRAM PROMPTS THE USER FOR INPUT DATA
 'ENTER THE PROBABILITY OF OCCURANCE OF THE FOLLOWING SITIUATIONS.'
 ''
 'EACH PROBABILITY MUST BE REPRESENTED AS A DECIMAL BETWEEN 0 AND 1.0.
 ''
 '1. PROBABILITY BEING DESTROYED WHILE EN ROUTE TO A FIRE POINT FROM'
 'THE TRANSLOAD POINT'
```

```
[31]  VAR[1]←⎕
[32]  '2. PROBABILITY OF VEHICULAR BREAK DOWN WHILE EN ROUTE TO'
[33]  'A FIRE POINT FROM THE TRANSLOAD POINT'
[34]  VAR[2]←⎕
[35]  '3. PROBABILITY OF BEING DESTROYED DURING BREAK DOWN WHILE ENROUT
[36]  'TO A FIRE POINT FROM THE TRANSLOAD POINT'
[37]  VAR[3]←⎕
[38]  '4. PROBABILITY OF A MISSION BEING ABORTED DUE TO A VEHICULAR'
[39]  'BREAK DOWN WHILE EN ROUTE TO A FIRE POINT FROM THE TRANSOAD POIN
[40]  'OR BATTERY POSITION'
[41]  VAR[4]←⎕
[42]  '5. PROBABILITY OF BEING DETECTED WHILE IN HIDE POSITION AT AN UNU
[43]  'FIRE POINT BEFORE A FIRE MISSION IS RECEIVED.'
[44]  VAR[5]←⎕
[45]  '6. PROBABILITY OF BEING GIVEN FIRE AT ''MY COMMAND'' VS ''WHEN'
[46]  'READY'' WHEN FIRING A MISSION FROM AN UNUSED FIRE POINT'
[47]  VAR[6]←⎕
[48]  '7. PROBABILITY OF BEING DETECTED WHEN THE LAUNCH PLATOON HAS LAI
[49]  'THE MISSILE BUT IS WAITING FOR THE COMMAND TO FIRE'
[50]  VAR[7]←⎕
[51]  '9. PROBABILITY OF BEING DETECTED IN THE HIDE POSITION AT A DETECT
[52]  'FIRE POINT BEFORE RECEIVING A MISSION.'
[53]  VAR[9]←⎕
[54]  '10. PROBABILITY OF BEING DESTROYED IN A DETECTED HIDE POSITION'
[55]  'AT A DETECTED FIRE POINT BEFORE RECEIVING A MISSION.'
[56]  VAR[10]←⎕
[57]  '11. PROBABILITY OF BEING DESTROYED WHILE LAYING THE MISSILE ON A'
[58]  'DETECTED FIRE POINT.'
[59]  VAR[11]←⎕
[60]  '12. PROBABILITY OF BEING GIVEN FIRE ''AT MY COMMAND'' VS ''WHEN '
[61]  'READY'' WHEN FIRING A MISSION FROM A DETECTED FIRE POINT'
[62]  VAR[12]←⎕
[63]  '13. PROBABILITY OF BEING DESTROYED WHILE AWAITING COMMAND TO FIRE
[64]  'WHEN FIRING A MISSION FROM DETECTED FIRE POINT'
```

```
[65]  VAR[13]←⎕
[66]  '14. PROBABILITY OF RECEIVING COMMAND TO FIRE VERSES ABORT MISSION'
[67]  'BEFORE BEING DESTROYED WHEN FIRING FROM A DETECTED FIRE POINT'
[68]  VAR[14]←⎕
[69]  '15. PROBABILITY OF BEING DESTROYED WHILE ENROUTE TO A NEW POINT'
[70]  'AFTER ABORTING A MISSION AT A DETECTED FIRE POINT.'
[71]  VAR[15]←⎕
[72]  '16. PROBABILITY OF VEHICULAR BREAK DOWN WHILE ENROUTE FROM ONE'
[73]  'FIRE POINT TO ANTOTHER.'
[74]  VAR[16]←⎕
[75]  '17. PROBABILITY OF BEING DESTROYED BEFORE TAKING ACTION TO'
[76]  'REPLACE DEFECTIVE ROUND AFTER MISFIRE AT AN UNDETECTED FIRE POINT.'
[77]  VAR[17]←⎕
[78]  '18. PROBABILITY OF TRANSLOADING A DEFECTIVE ROUND AFTER MISFIRE AT'
[79]  'A DETECTED POINT VERSES TRANSLOADING THE ROUND WHILE ENROUTE TO'
[80]  'ANOTHER FIRE POINT.'
[81]  VAR[18]←⎕
[82]  '20. PROBABILITY OF ABORTING MISSION BECAUSE OF DEFECTIVE MISSILE AT'
[83]  'A DETECTED FIRE POINT (DO NOT TRANSLOAD AND CONTINUE WITH MISSION)'
[84]  VAR[20]←⎕
[85]  '21. PROBABILITY OF BEING DESTROYED WHILE RECOVERING OR DISPLACING'
[86]  'AFTER A SUCCESSFUL FIRE MISSION'
[87]  VAR[21]←⎕
[88]  '22. PROBABILITY TRANSLOADING AND FIRING AGAIN AT THE SAME FIRE POINT
[89]  'VERSES TRANSLOADING EN ROUTE TO ANOTHER POINT.'
[90]  VAR[22]←⎕
[91]  '24. PROBABILITY OF RECEIVING A MISSION WHILE TRANSLOADING ENROUTE'
[92]  'TO A FIRE POINT'
[93]  VAR[24]←⎕
[94]  '25. PROBABILITY OF BEING DESTROYED WHILE TRANSLOADING AT THE FIRE'
[95]  'POINT AFTER A FIRE MISSION'
[96]  VAR[25]←⎕
[97]  '26. PROBABILITY OF RECEIVING A MISSION WHILE TRANSLOADING AT THE'
[98]  'FIRE POINT AFTER A SUCCESSFUL FIRE MISSION'
```

```
VAR[26]←⎕
'27. PROBABILITY OF BEING DESTROYED WHILE TRANSLOADING AT A DETE
'FIRE POINT AFTER A MISFIRE'
VAR[27]←⎕
'28. PROBABILITY OF TRANSLOADING AND AT THE SAME DETECTED FIRE P
'AFTER A MISFIRE AND CONTINUING THE FIRE MISSION'
'VERSES TRANSLOADING AT THE POINT, ABORTING THE MISSION AND GOIN
'THE HIDE POSITION FOR THAT FIRE POINT.'
VAR[28]←⎕
'29. PROBABILITY OF BEING DESTROYED WHILE TRANSLOADING AT AN'
'UNDETECTED FIRE POINT AFTER A MISFIRE'
VAR[29]←⎕
'30. PROBABILITY OF BEING DETECTED WHILE TRANSLOADING AT A NEW F
'POINT AFTER A MISFIRE'
VAR[30]←⎕
'31. PROBABILITY OF ABORTING MISSION BECAUSE OF A MISFIRE ON A N
'POINT AND MOVING TO THE HIDE POSITION AT THAT POINT'
VAR[31]←⎕
'32. PROBABILITY OF BEING DESTROYED WHILE TRANSLOADING EN ROUTE
'A DETECTED FIRE POINT TO A NEW OR UNDETECTED FIRE POINT.'
VAR[32]←⎕
'34. PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN, TRANSLOAD
'EN ROUTE TO A NEW FIRE POINT'
VAR[34]←⎕
'35. PROBABILITY OF DESTRUCTION WHILE TRANSLOADING EN ROUTE TO A
'DETECTED FIRE POINT.'
VAR[35]←⎕
'37. PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN, TRANSLOAD
'EN ROUTE TO A USED FIRE POINT'
VAR[37]←⎕
'38. PROBABILITY OF BEING DESTROYED WHILE EN ROUTE FROM A FIRE P
'TO THE LOCAL TRANSLOAD POINT'
VAR[38]←⎕
'39. PROBABILITY OF VEHICULAR BREAK DOWN WHILE EN ROUTE'
```

```
[133]  'TO THE LOCAL TRANSLOAD POINT'
[134]  VAR[39]←⎕
[135]  '40. PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN WHILE ENROUTE'
[136]  'TO THE LOCAL TRANSLOAD POINT'
[137]  VAR[40]←⎕
[138]  '41. PROBABILITY OF BEING DESTROYED WHILE AT LOCAL TRANSLOAD POINT'
[139]  VAR[41]←⎕
[140]  '42. PROBABILITY OF RECEIVING A FIRE MISSION PRIOR TO ARRIVING AT'
[141]  'THE FIRE POINT AFTER TRANSLOADING(BATTERY OR LOCAL TRANSLOAD POINT)
[142]  VAR[42]←⎕
[143]  '45. PROBABILITY OF A MISFIRE ON FIRST ATTEMPT TO FIRE A MISSILE '
[144]  VAR[45]←⎕
[145]  '46. PROBABILITY OF SUCCESSFULLY FIRING THE MISSILE WHICH FORMERLY'
[146]  'MISFIRED BUT WAS SERVICABLE.(UNEXPLAINED NO GO)'
[147]  VAR[46]←⎕
[148]  '47. PROBABILITY THAT A FIRING POINT IS UNUSED AND UNDETECTED VERSES
[149]  'USED (FIRED FROM, ASSUMED TO BE DETECTED)'
[150]  VAR[47]←⎕
[151]  '50. PROBABILITY OF BEING DESTROYED WHILE EN ROUTE BETWEEN A FIRE'
[152]  'POINT AND THE BATTERY AREA FOR TRANSLOAD OPERATIONS'
[153]  VAR[50]←⎕
[154]  '51. PROBABILITY OF VEHICULAR BREAK DOWN WHILE EN ROUTE'
[155]  'TO BATTERY AREA FOR TRANSLOAD OPERATIONS'
[156]  VAR[51]←⎕
[157]  '52. PROBABILITY OF BEING DESTROYED WHILE BROKEN DOWN WHILE ENROUTE'
[158]  'TO BATTERY AREA FOR TRANSLOAD OPERATIONS'
[159]  VAR[52]←⎕
[160]  '53. PROBABILITY OF BEING DESTROYED WHILE AT THE BATTERY AREA'
[161]  VAR[53]←⎕
[162]
[163]  PROG1MTX
[164]  PROG2MTX
[165]  PROG3MTX
     ∇
```

APPENDIX H.

```
      ∇ PROG1MTX
[1]   ⍝THIS FUNCTION USES THE VECTOR OF INPUT PROBABILITIES FROM VECTOR '
[2]   ⍝TO CREATE THE FIRST LEVEL OF THE P(I,J) MATRIX.
[3]    ''
[4]   ⍝FIRST A 93 BY 93 MATRIX OF ZEROS IS CREATED
[5]    PIJM← 93 93 ⍴0
[6]    ''
[7]   ⍝NEXT THE VALUES FOR VALUES OF 'P' ARE COMPUTED AND INPUT INTO THE
[8]   ⍝MATRIX PIJM. EACH STATE 'I' IS LISTED WITH THE STATES 'J' TO WHICH
[9]   ⍝IT CAN TRANSITION TO.  SIMILAR STATES ARE GROUPED TOGETHER
[10]   ''
[11] ⍝   MOVING TO AND SHOOTING FROM A POINT'
[12] ⍝1  ENROUTE TO NEW FIRE POINT                               2,5 AND 92
[13] ⍝3  ENROUTE TO NEW FIRE POINT WITH A MISSION                4,6 AND 92
[14] ⍝9  ENROUTE TO DETECTED FIRE POINT                        10,13 AND 92
[15] ⍝11 ENROUTE TO DETECTED FIRE POINT WITH A MISSION         12,15 AND 92
[16]  PIJM[(1,3,9,11);92]←VAR[1]
[17]  PIJM[1;2]←VAR[2]×(1-VAR[1])
[18]  PIJM[3;4]←VAR[2]×(1-VAR[1])
[19]  PIJM[9;10]←VAR[2]×(1-VAR[1])
[20]  PIJM[11;12]←VAR[2]×(1-VAR[1])
[21] ⍝THE PROBABILITY OF ARRIVING AT FIRE POINT WITHOUT INCIDENT
[22]  PIJM[1;5]←(1-VAR[2])×(1-VAR[1])
[23]  PIJM[3;6]←(1-VAR[2])×(1-VAR[1])
[24]  PIJM[9;13]←(1-VAR[2])×(1-VAR[1])
[25]  PIJM[11;15]←(1-VAR[2])×(1-VAR[1])
[26] ⍝2 DOWN ENROUTE TO NEW FIRE POINT                              5 AND 92
[27] ⍝4 DOWN ENROUTE TO NEW FIRE POINT WITH MISSION               5,6 AND 92
[28] ⍝10 DOWN ENROUT TO USED FIRE POINT                            13 AND 92
[29] ⍝12 DOWN ENROUT TO USED FIRE POINT WITH MISSION            13,15 AND 92
[30]  PIJM[(2,4,10,12);92]←VAR[3]
```

```
[31]  PIJM[4;5]←VAR[4]×(1-VAR[3])
[32]  PIJM[12;13]←VAR[4]×(1-VAR[3])
[33] ⍝PROBABILITY OF ARRIVING AT FIRE POINT AFTER UP(WITH MISSION)
[34]  PIJM[2;5]←(1-VAR[3])
[35]  PIJM[4;6]←(1-VAR[3])×(1-VAR[4])
[36]  PIJM[10;13]←(1-VAR[3])
[37]  PIJM[12;15]←(1-VAR[3])×(1-VAR[4])
[38] ⍝5 IN HIDE POSITION AT NEW POINT WAITING FOR MISSION                  6,14
[39]  PIJM[5;14]←VAR[5]
[40] ⍝PROBABILITY OF GETTING A MISSION BEFORE BEING DETECTED
[41]  PIJM[5;6]←(1-VAR[5])
[42] ⍝6 ON NEW POINT WITH MISSION LAYING                                 7,8,19
[43]  PIJM[6;7]←(1-VAR[45])×VAR[6]
[44]  PIJM[6;8]←VAR[45]
[45] ⍝PROBABILITY OF FIRING WHEN READY (AND MISSILE FIRES)'
[46]  PIJM[6;19]←(1-VAR[45])×(1-VAR[6])
[47] ⍝7 NEW POINT LAID WAITING FIRE COMMAND                             8,16,19
[48]  PIJM[7;8]←VAR[45]
[49]  PIJM[7;16]←(1-VAR[45])×VAR[7]
[50] ⍝PROBABILITY OF SHOOTING WHEN COMMANDED BEFORE DETECTION'
[51]  PIJM[7;19]←(1-VAR[45])×(1-VAR[7])
[52] ⍝STATE 8 MISFIRE ON NEW POINT                                     19,22,31
[53]  PIJM[8;19]←VAR[46]
[54]  PIJM[8;22]←(1-VAR[46])×VAR[8]
[55] ⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND'
[56]  PIJM[8;31]←(1-VAR[46])×(1-VAR[8])
[57] ⍝   SHOOTING FROM A USED POINT(ADDITIONAL CONSIDERATIONS'
[58] ⍝13 IN HIDE POSITION AT USED POINT WAITING FOR MISSION               14,15
[59]  PIJM[13;14]←VAR[9]
[60] ⍝PROBABILITY OF GETTING A MISSION
[61]  PIJM[13;15]←(1-VAR[9])
[62] ⍝14 IN HIDE POSITION DETECTED WAITING FOR MISSION                    15,93
[63]  PIJM[14;93]←VAR[10]
[64] ⍝PROBABILITY OF GETTING A MISSION BEFORE BEING DESTROYED IN HIDE(PD)
```

```
[65]  PIJM[14;15]←(1-VAR[10])
[66] ⍝15 ON USED (DETECTED) POINT WITH MISSION LAYING            16,18,19,
[67]  PIJM[15;93]←VAR[11]
[68]  PIJM[15;16]←(1-VAR[45])×(1-VAR[11])×VAR[12]
[69]  PIJM[15;18]←VAR[45]×(1-VAR[11])
[70] ⍝PROBABILITY OF SHOOTING WHEN READY
[71]  PIJM[15;19]←(1-VAR[45])×(1-VAR[11])×(1-VAR[12])
[72] ⍝16 ON USED (DETECTED) POINT LAID WAITING COMMAND          17,18,19,9
[73]  PIJM[16;93]←VAR[13]
[74]  PIJM[16;19]←(1-VAR[45])×(1-VAR[13])×VAR[14]
[75]  PIJM[16;18]←VAR[45]×(1-VAR[13])×VAR[14]
[76]  PIJM[16;17]←(1-VAR[13])×(1-VAR[14])
[77] ⍝17 ABORT MISSION GO TO NEW POINT                                  2,5,9
[78]  PIJM[17;93]←VAR[15]
[79]  PIJM[17;2]←VAR[16]×(1-VAR[15])
[80] ⍝PROBABILITY OF GETTING TO POINT WITHOUT INCEDENT
[81]  PIJM[17;5]←(1-VAR[16])×(1-VAR[15])
[82] ⍝18 MISFIRE ON USED (DETECTED) POINT        19,21,23,25,27,29,31,9
[83] ⍝ROUND FIRES ON SUBSEQUENT TRY
[84]  PIJM[18;19]←VAR[46]
[85]  PIJM[18;93]←(1-VAR[46])×VAR[17]
[86]  PIJM[18;21]←(1-VAR[46])×(1-VAR[17])×VAR[18]×VAR[19]
[87] ⍝ PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POINT ABORT MISSION'
[88]  PIJM[18;23]←(1-VAR[46])×(1-VAR[17])×(1-VAR[18])×VAR[19]×VAR[20]
[89] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POINT SAME MISSION'
[90]  PIJM[18;25]←(1-VAR[46])×(1-VAR[17])×(1-VAR[18])×VAR[19]×(1-VAR[20]
[91] ⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND****
[92]  PIJM[18;31]←(1-VAR[46])×(1-VAR[17])×(1-VAR[19])
[93] ⍝19 MISSILE SHOT DISPLACING                            20,23,25,27,29,31,
[94]  PIJM[19;93]←VAR[21]
[95]  PIJM[19;20]←(1-VAR[21])×VAR[22]×VAR[23]
[96] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POSITION'
[97]  PIJM[19;23]←(1-VAR[21])×(1-VAR[22])×VAR[23]×(1-VAR[24])×VAR[47]
[98] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO USED POSITION'
```

```
PIJM[19;27]←(1-VAR[21])×(1-VAR[22])×VAR[23]×(1-VAR[24])×(1-VAR[47])
⍝ PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POSITION WITH MISSION'
 PIJM[19;25]←(1-VAR[21])×(1-VAR[22])×VAR[23]×VAR[24]×VAR[47]
⍝PROBABILITY OF TRANSLOAD EN ROUTE TO USED POSITION WITH MISSION'
 PIJM[19;29]←(1-VAR[21])×(1-VAR[22])×VAR[23]×VAR[24]×(1-VAR[47])
⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND'
 PIJM[19;31]←(1-VAR[21])×(1-VAR[23])
⍝20 TRANSLOAD AT USED FIRE POINT(AFTER MISSION)          47,48,93
 PIJM[20;93]←VAR[25]
 PIJM[20;48]←(1-VAR[25])×VAR[26]
⍝PROBABILITY GOING TO A HIDE POSITION TO AWAIT MISSION
 PIJM[20;47]←(1-VAR[25])×(1-VAR[26])
⍝21 TRANSLOAD AT USED FIRE POINT AFTER MISFIRE           46,48,93
 PIJM[21;93]←VAR[27]
 PIJM[21;48]←(1-VAR[27])×VAR[28]
⍝PROBABILITY OF GOING TO HIDE POSITION WITHOUT'
 PIJM[21;46]←(1-VAR[27])×(1-VAR[28])
⍝22 TRANSLOAD AT SAME FIRE POINT AFTER MISFIRE     38,39,47,48,93
 PIJM[22;93]←VAR[29]
⍝PROBABILITY OF ABORTING THEN HIDE POSITION WITHOUT BEING DETECTED'
 PIJM[22;38]←(1-VAR[29])×(1-VAR[30])×VAR[31]
⍝PROB OF CONTINUING MISSION AT POINT AFTER TRANSLOAD UNDETECTED'
 PIJM[22;39]←(1-VAR[29])×(1-VAR[30])×(1-VAR[31])
⍝PROB OF ABORTING THEN HIDE POSITION BECOMING DETECTED'
 PIJM[22;47]←(1-VAR[29])×VAR[30]×VAR[31]
⍝PROB OF CONTINUING MISSION AT POINT AFTER TRANSLOAD DETECTED'
 PIJM[22;48]←(1-VAR[29])×VAR[30]×(1-VAR[31])
⍝23 TRANSLOAD EN ROUTE TO NEW FIRE POINT                   38,24,94
⍝25 TRANSLOAD EN ROUTE TO NEW FIRE POINT WITH MISSION      39,26,94
 PIJM[(23,25);89]←VAR[32]
 PIJM[23;24]←VAR[16]×(1-VAR[32])
 PIJM[25;26]←VAR[16]×(1-VAR[32])
⍝PROBABILITY OF GOING TO NEW POINT OR HIDE POSITION
 PIJM[23;38]←(1-VAR[16])×(1-VAR[32])
```

```
[133]  PIJM[25;39]←(1-VAR[16])×(1-VAR[32])
[134] ⍝24 DOWN TRANSLOADING EN ROUTE TO NEW FIRE POINT                38,9
[135] ⍝26 DOWN TRANSLOADING EN ROUTE TO NEW FIRE POINT WITH MISSION 39,9
[136]  PIJM[(24,26);89]←VAR[34]
[137] ⍝PROBABILITY OF ARRIVING AT NEW POINT
[138]  PIJM[24;38]←(1-VAR[34])
[139]  PIJM[26;39]←(1-VAR[34])
[140] ⍝27 TRANSLOAD EN ROUTE TO USED FIRE POINT                    46,28,9
[141] ⍝29 TRANSLOAD EN ROUTE TO USED FIRE POINT                    48,30,9
[142]  PIJM[(27,29);89]←VAR[35]
[143]  PIJM[27;28]←(1-VAR[35])×VAR[16]
[144]  PIJM[29;30]←(1-VAR[35])×VAR[16]
[145] ⍝PROBABILITY OF GOING TO USED POINT OR HIDE POSITIONAT USED POINT
[146]  PIJM[27;46]←(1-VAR[35])×(1-VAR[16])
[147]  PIJM[29;48]←(1-VAR[35])×(1-VAR[16])
[148] ⍝28 DOWN TRANSLOADING EN ROUTE TO USED FIRE POINT               46,9
[149] ⍝30 DOWN TRANSLOADING EN ROUTE TO USED FIRE POINT W/MISSION   48,9
[150]  PIJM[(28,30);89]←VAR[37]
[151] ⍝PROBABILITY OF ARRIVING AT NEW POINT'
[152]  PIJM[28;46]←(1-VAR[37])
[153]  PIJM[30;48]←(1-VAR[37])
[154] ⍝31 ENROUTE TO TRANSLOAD POINT                               32,33,9
[155]  PIJM[31;90]←VAR[38]
[156]  PIJM[31;32]←VAR[39]×(1-VAR[38])
[157] ⍝PROBABILITY OF ARRIVING AT POINT WITHOUT INCIDENT
[158]  PIJM[31;33]←(1-VAR[39])×(1-VAR[38])
[159] ⍝32 DOWN WHILE ENROUTE TO TRANSLOAD POINT                       33,9
[160]  PIJM[32;90]←VAR[40]
[161] ⍝PROBABILBITY OF ARRIVING AT TRANSLOAD POINT
[162]  PIJM[32;33]←(1-VAR[40])
[163] ⍝33 TRANSLOADING AT TRANSLOAD POINT                      34,36,42,44,9
[164]  PIJM[33;91]←VAR[41]
[165] ⍝PROBABILITY GOING TO A NEW POINT WITHOUT A MISSION'
[166]  PIJM[33;34]←(1-VAR[41])×(1-VAR[42])×VAR[47]
```

```
[167] ⍝PROBABILTY OF GOING TO A NEW POINT WITH A MISSION
[168]  PIJM[33;36]←(1-VAR[41])×VAR[42]×VAR[47]
[169] ⍝PROBABILITY OF GOING TO A USED POINT WITHOUT A MISSION
[170]  PIJM[33;42]←(1-VAR[41])×(1-VAR[42])×(1-VAR[47])
[171]  PIJM[33;44]←(1-VAR[41])×VAR[42]×(1-VAR[47])
      ∇
```

APPENDIX I.

```
      ∇ PROG2MTX
[1]   ⍝THIS FUNCTION USES A SERIES OF PROBABILITY VALUES FROM VECTOR (VAR
[2]   ⍝TO CREATE THE SECOND LEVEL OF THE P(I,J) MATRIX.
[3]   ⍝(SEE EXPLANATION FOR PROG1MTX)
[4]   ⍝   MOVING TO AND SHOOTING FROM A POINT'
[5]   ⍝34 ENROUTE TO NEW FIRE POINT                          35,38 AND 92
[6]   ⍝36 ENROUTE TO NEW FIRE POINT WITH A MISSION           37,39 AND 92
[7]   ⍝42 ENROUTE TO USED FIRE POINT                         43,46 AND 92
[8]   ⍝44 ENROUTE TO USED FIRE POINT WITH A MISSION          45,48 AND 92
[9]    PIJM[(34,36,42,44);92]←VAR[1]
[10]   PIJM[34;35]←VAR[2]×(1-VAR[1])
[11]   PIJM[36;37]←VAR[2]×(1-VAR[1])
[12]   PIJM[42;43]←VAR[2]×(1-VAR[1])
[13]   PIJM[44;45]←VAR[2]×(1-VAR[1])
[14]  ⍝THE PROBABILITY OF ARRIVING AT FIRE POINT WITHOUT INCIDENT
[15]   PIJM[34;38]←(1-VAR[2])×(1-VAR[1])
[16]   PIJM[36;39]←(1-VAR[2])×(1-VAR[1])
[17]   PIJM[42;46]←(1-VAR[2])×(1-VAR[1])
[18]   PIJM[44;48]←(1-VAR[2])×(1-VAR[1])
[19]  ⍝35 DOWN ENROUTE TO NEW FIRE POINT                           38 AND 9
[20]  ⍝37 DOWN ENROUTE TO NEW FIRE POINT WITH MISSION           38,39 AND 9
[21]  ⍝43 DOWN ENROUT TO USED FIRE POINT                           46 AND 9
[22]  ⍝45 DOWN ENROUT TO USED FIRE POINT WITH MISSION           46,47 AND 9
[23]   PIJM[(35,37,43,45);92]←VAR[3]
[24]   PIJM[37;38]←VAR[4]×(1-VAR[3])
[25]   PIJM[45;46]←VAR[4]×(1-VAR[3])
[26]  ⍝PROBABILITY OF ARRIVING AT FIRE POINT AFTER UP(WITH MISSION)
[27]   PIJM[35;38]←(1-VAR[3])
[28]   PIJM[37;39]←(1-VAR[3])×(1-VAR[4])
[29]   PIJM[43;46]←(1-VAR[3])
[30]   PIJM[45;47]←(1-VAR[3])×(1-VAR[4])
```

```
[31] ⍝38 IN HIDE POSITION AT NEW POINT WAITING FOR MISSION                39,47
[32]  PIJM[38;47]←VAR[5]
[33] ⍝PROBABILITY OF GETTING A MISSION BEFORE BEING DETECTED
[34]  PIJM[38;39]←(1-VAR[5])
[35] ⍝39 ON NEW POINT WITH MISSION LAYING                               40,41,52
[36]  PIJM[39;40]←(1-VAR[45])×VAR[6]
[37]  PIJM[39;41]←VAR[45]
[38] ⍝PROBABILITY OF FIRING WHEN READY (AND MISSILE FIRES)'
[39]  PIJM[39;52]←(1-VAR[45])×(1-VAR[6])
[40] ⍝40 NEW POINT LAID WAITING FIRE COMMAND                            41,49,52
[41]  PIJM[40;41]←VAR[45]
[42]  PIJM[40;49]←(1-VAR[45])×VAR[7]
[43] ⍝PROBABILITY OF SHOOTING WHEN COMMANDED BEFORE DETECTION'
[44]  PIJM[40;52]←(1-VAR[45])×(1-VAR[7])
[45] ⍝STATE 41 MISFIRE ON NEW POINT                                     52,55,64
[46]  PIJM[41;52]←VAR[46]
[47]  PIJM[41;55]←(1-VAR[46])×VAR[8]
[48] ⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND'
[49]  PIJM[41;64]←(1-VAR[46])×(1-VAR[8])
[50] ⍝   SHOOTING FROM A USED POINT(ADDITIONAL CONSIDERATIONS'
[51] ⍝46 IN HIDE POSITION AT USED POINT WAITING FOR MISSION               47,48
[52]  PIJM[46;47]←VAR[9]
[53] ⍝PROBABILITY OF GETTING A MISSION
[54]  PIJM[46;48]←(1-VAR[9])
[55] ⍝47 IN HIDE POSITION DETECTED WAITING FOR MISSION                   48,93
[56]  PIJM[47;93]←VAR[10]
[57] ⍝PROBABILITY OF GETTING A MISSION BEFORE BEING DESTROYED IN HIDE(PD)
[58]  PIJM[47;48]←(1-VAR[10])
[59] ⍝48 ON USED (DETECTED) POINT WITH MISSION LAYING               49,51,52,93
[60]  PIJM[48;93]←VAR[11]
[61]  PIJM[48;49]←(1-VAR[45])×(1-VAR[11])×VAR[12]
[62]  PIJM[48;51]←VAR[45]×(1-VAR[11])
[63] ⍝PROBABILITY OF SHOOTING WHEN READY
[64]  PIJM[48;52]←(1-VAR[45])×(1-VAR[11])×(1-VAR[12])
```

```
[65] ⍝49 ON USED (DETECTED) POINT LAID WAITING COMMAND           50,51,52,93
[66]  PIJM[49;93]←VAR[13]
[67]  PIJM[49;50]←(1-VAR[45])×(1-VAR[13])×VAR[14]
[68]  PIJM[49;51]←VAR[45]×(1-VAR[13])×VAR[14]
[69]  PIJM[49;52]←(1-VAR[13])×(1-VAR[14])
[70] ⍝50 ABORT MISSION GO TO NEW POINT                               35,38,93
[71]  PIJM[50;93]←VAR[15]
[72]  PIJM[50;35]←VAR[16]×(1-VAR[15])
[73] ⍝PROBABILITY OF GETTING TO POINT WITHOUT INCEDENT
[74]  PIJM[50;38]←(1-VAR[16])×(1-VAR[15])
[75] ⍝51 MISFIRE ON USED (DETECTED) POINT               52,54,56,58,60,62,64
[76] ⍝ROUND FIRES ON SUBSEQUENT TRY
[77]  PIJM[51;52]←VAR[46]
[78]  PIJM[51;93]←(1-VAR[46])×VAR[17]
[79]  PIJM[51;54]←(1-VAR[46])×(1-VAR[17])×VAR[18]×VAR[19]
[80] ⍝ PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POINT ABORT MISSION'
[81]  PIJM[51;56]←(1-VAR[46])×(1-VAR[17])×(1-VAR[18])×VAR[19]×VAR[20]
[82] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POINT SAME MISSION'
[83]  PIJM[51;58]←(1-VAR[46])×(1-VAR[17])×(1-VAR[18])×VAR[19]×(1-VAR[20]
[84] ⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND
[85]  PIJM[51;64]←(1-VAR[46])×(1-VAR[17])×(1-VAR[19])
[86] ⍝52 MISSILE SHOT DISPLACING                           53,56,58,60,62,64,
[87]  PIJM[52;93]←VAR[21]
[88]  PIJM[52;53]←(1-VAR[21])×VAR[22]×VAR[23]
[89] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POSITION'
[90]  PIJM[52;56]←(1-VAR[21])×(1-VAR[22])×VAR[23]×(1-VAR[24])×VAR[47]
[91] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO USED POSITION'
[92]  PIJM[52;60]←(1-VAR[21])×(1-VAR[22])×VAR[23]×(1-VAR[24])×(1-VAR[47]
[93] ⍝ PROBABILITY OF TRANSLOAD EN ROUTE TO NEW POSITION WITH MISSION'
[94]  PIJM[52;58]←(1-VAR[21])×(1-VAR[22])×VAR[23]×VAR[24]×VAR[47]
[95] ⍝PROBABILITY OF TRANSLOAD EN ROUTE TO USED POSITION WITH MISSION'
[96]  PIJM[52;62]←(1-VAR[21])×(1-VAR[22])×VAR[23]×VAR[24]×(1-VAR[47])
[97] ⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND'
[98]  PIJM[52;64]←(1-VAR[21])×(1-VAR[23])
```

```
[99] ⍝53 TRANSLOAD AT USED FIRE POINT(AFTER MISSION)          80,81,93
[100]  PIJM[53;93]←VAR[25]
[101]  PIJM[53;81]←(1-VAR[25])×VAR[26]
[102] ⍝PROBABILITY GOING TO A HIDE POSITION TO AWAIT MISSION
[103]  PIJM[53;80]←(1-VAR[25])×(1-VAR[26])
[104] ⍝54 TRANSLOAD AT USED FIRE POINT AFTER MISFIRE            79,81,93
[105]  PIJM[54;93]←VAR[27]
[106]  PIJM[54;81]←(1-VAR[27])×VAR[28]
[107] ⍝PROBABILITY OF GOING TO HIDE POSITION WITHOUT'
[108]  PIJM[54;79]←(1-VAR[27])×(1-VAR[28])
[109] ⍝55 TRANSLOAD AT SAME FIRE POINT AFTER MISFIRE       71,72,80,81,93
[110]  PIJM[55;93]←VAR[29]
[111] ⍝PROBABILITY OF ABORTING THEN HIDE POSITION WITHOUT BEING DETECTED'
[112]  PIJM[55;71]←(1-VAR[29])×(1-VAR[30])×VAR[31]
[113] ⍝PROB OF CONTINUING MISSION AT POINT AFTER TRANSLOAD UNDETECTED'
[114]  PIJM[55;72]←(1-VAR[29])×(1-VAR[30])×(1-VAR[31])
[115] ⍝PROB OF ABORTING THEN HIDE POSITION BECOMING DETECTED'
[116]  PIJM[55;80]←(1-VAR[29])×VAR[30]×VAR[31]
[117] ⍝PROB OF CONTINUING MISSION AT POINT AFTER TRANSLOAD DETECTED'
[118]  PIJM[55;81]←(1-VAR[29])×VAR[30]×(1-VAR[31])
[119] ⍝56 TRANSLOAD EN ROUTE TO NEW FIRE POINT                   71,57,94
[120] ⍝58 TRANSLOAD EN ROUTE TO NEW FIRE POINT WITH MISSION      72,59,94
[121]  PIJM[(56,58);89]←VAR[32]
[122]  PIJM[56;57]←VAR[16]×(1-VAR[32])
[123]  PIJM[58;59]←VAR[16]×(1-VAR[32])
[124] ⍝PROBABILITY OF GOING TO NEW POINT OR HIDE POSITION
[125]  PIJM[56;71]←(1-VAR[16])×(1-VAR[32])
[126]  PIJM[58;72]←(1-VAR[16])×(1-VAR[32])
[127] ⍝57 DOWN TRANSLOADING EN ROUTE TO NEW FIRE POINT                71,94
[128] ⍝59 DOWN TRANSLOADING EN ROUTE TO NEW FIRE POINT WITH MISSION 72,94
[129]  PIJM[(57,59);89]←VAR[34]
[130] ⍝PROBABILITY OF ARRIVING AT NEW POINT
[131]  PIJM[57;71]←(1-VAR[34])
[132]  PIJM[59;72]←(1-VAR[34])
```

```
⍝60 TRANSLOAD EN ROUTE TO USED FIRE POINT                          79,61,9
⍝62 TRANSLOAD EN ROUTE TO USED FIRE POINT                          81,63,9
 PIJM[(60,62);89]←VAR[35]
 PIJM[60;61]←(1-VAR[35])×VAR[16]
 PIJM[62;63]←(1-VAR[35])×VAR[16]
⍝PROBABILITY OF GOING TO USED POINT OR HIDE POSITIONAT USED POINT
 PIJM[60;79]←(1-VAR[35])×(1-VAR[16])
 PIJM[62;81]←(1-VAR[35])×(1-VAR[16])
⍝61 DOWN TRANSLOADING EN ROUTE TO USED FIRE POINT                     79,9
⍝63 DOWN TRANSLOADING EN ROUTE TO USED FIRE POINT W/MISSION           81,9
 PIJM[(61,63);89]←VAR[37]
⍝PROBABILITY OF ARRIVING AT NEW POINT'
 PIJM[61;79]←(1-VAR[37])
 PIJM[63;81]←(1-VAR[37])
⍝64 ENROUTE TO BATTERY POSITION                                    65,88,9
 PIJM[64;90]←VAR[38]
 PIJM[64;65]←VAR[39]×(1-VAR[38])
⍝PROBABILITY OF ARRIVING AT POINT WITHOUT INCIDENT
 PIJM[64;88]←(1-VAR[39])×(1-VAR[38])
⍝65 DOWN WHILE ENROUTE TO TRANSLOAD POINT                             88,9
 PIJM[65;90]←VAR[40]
⍝PROBABILBITY OF ARRIVING AT TRANSLOAD POINT
 PIJM[65;88]←(1-VAR[40])
⍝66 TRANSLOADING AT TRANSLOAD POINT                          67,69,75,77,91
 PIJM[66;91]←VAR[41]
⍝PROBABILITY GOING TO A NEW POINT WITHOUT A MISSION'
 PIJM[66;67]←(1-VAR[41])×(1-VAR[42])×VAR[47]
⍝PROBABILTY OF GOING TO A NEW POINT WITH A MISSION
 PIJM[66;69]←(1-VAR[41])×VAR[42]×VAR[47]
⍝PROBABILITY OF GOING TO A USED POINT WITHOUT A MISSION
 PIJM[66;75]←(1-VAR[41])×(1-VAR[42])×(1-VAR[47])
 PIJM[66;77]←(1-VAR[41])×VAR[42]×(1-VAR[47])
∇
```

APPENDIX J.

```
      ∇ PROG3MTX
[1]   ⍝THIS PROGRAM USES A SERIES OF PROBABILITY VALUES FROM A VECTOR (VAR)
[2]   ⍝TO CREATE THE THIRD LEVEL OF THE P(I,J) MATRIX.
[3]   ⍝SEE PROG1MTX FOR EXPLANTATION
[4]    ''
[5]   ⍝   MOVING TO AND SHOOTING FROM A POINT'
[6]   ⍝67 ENROUTE TO NEW FIRE POINT                          68,71 AND 92
[7]   ⍝69 ENROUTE TO NEW FIRE POINT WITH A MISSION           70,72 AND 92
[8]   ⍝75 ENROUTE TO USED FIRE POINT                         76,79 AND 92
[9]   ⍝77 ENROUTE TO USED FIRE POINT WITH A MISSION          78,81 AND 92
[10]   PIJM[(67,69,75,77);92]←VAR[1]
[11]   PIJM[67;68]←VAR[2]×(1-VAR[1])
[12]   PIJM[69;70]←VAR[2]×(1-VAR[1])
[13]   PIJM[75;76]←VAR[2]×(1-VAR[1])
[14]   PIJM[77;78]←VAR[2]×(1-VAR[1])
[15]  ⍝THE PROBABILITY OF ARRIVING AT FIRE POINT WITHOUT INCIDENT
[16]   PIJM[67;71]←(1-VAR[2])×(1-VAR[1])
[17]   PIJM[69;72]←(1-VAR[2])×(1-VAR[1])
[18]   PIJM[75;79]←(1-VAR[2])×(1-VAR[1])
[19]   PIJM[77;81]←(1-VAR[2])×(1-VAR[1])
[20]  ⍝68 DOWN ENROUTE TO NEW FIRE POINT                          71 AND 92
[21]  ⍝70 DOWN ENROUTE TO NEW FIRE POINT WITH MISSION          71,72 AND 92
[22]  ⍝76 DOWN ENROUT TO USED FIRE POINT                          79 AND 92
[23]  ⍝78 DOWN ENROUT TO USED FIRE POINT WITH MISSION          79,81 AND 92
[24]   PIJM[(68,70,76,78);92]←VAR[3]
[25]   PIJM[70;71]←VAR[4]×(1-VAR[3])
[26]   PIJM[78;79]←VAR[4]×(1-VAR[3])
[27]  ⍝PROBABILITY OF ARRIVING AT FIRE POINT AFTER UP(WITH MISSION)
[28]   PIJM[68;71]←(1-VAR[3])
[29]   PIJM[70;72]←(1-VAR[3])×(1-VAR[4])
[30]   PIJM[76;79]←(1-VAR[3])
```

```
[31]  PIJM[78;81]←(1-VAR[3])×(1-VAR[4])
[32] ⍝71 IN HIDE POSITION AT NEW POINT WAITING FOR MISSION            72,8
[33]  PIJM[71;80]←VAR[5]
[34] ⍝PROBABILITY OF GETTING A MISSION BEFORE BEING DETECTED
[35]  PIJM[71;72]←(1-VAR[5])
[36] ⍝72 ON NEW POINT WITH MISSION LAYING                          73,74,8
[37]  PIJM[72;73]←(1-VAR[45])×VAR[6]
[38]  PIJM[72;74]←VAR[45]
[39] ⍝PROBABILITY OF FIRING WHEN READY (AND MISSILE FIRES)'
[40]  PIJM[72;85]←(1-VAR[45])×(1-VAR[6])
[41] ⍝73 NEW POINT LAID WAITING FIRE COMMAND                       74,82,8
[42]  PIJM[73;74]←VAR[45]
[43]  PIJM[73;82]←(1-VAR[45])×VAR[7]
[44] ⍝PROBABILITY OF SHOOTING WHEN COMMANDED BEFORE DETECTION'
[45]  PIJM[73;85]←(1-VAR[45])×(1-VAR[7])
[46] ⍝74 MISFIRE ON NEW POINT                                         85,8
[47]  PIJM[74;85]←VAR[46]
[48] ⍝PROBABILITY OF GOING TO TRANSLOAD POINT TO GET ANOTHER ROUND'
[49]  PIJM[74;86]←(1-VAR[46])
[50] ⍝   SHOOTING FROM A USED POINT(ADDITIONAL CONSIDERATIONS'
[51] ⍝79 IN HIDE POSITION AT USED POINT WAITING FOR MISSION          80,81
[52]  PIJM[79;80]←VAR[9]
[53] ⍝PROBABILITY OF GETTING A MISSION
[54]  PIJM[79;81]←(1-VAR[9])
[55] ⍝80 IN HIDE POSITION DETECTED WAITING FOR MISSION               81,93
[56]  PIJM[80;93]←VAR[10]
[57] ⍝PROBABILITY OF GETTING A MISSION BEFORE BEING DESTROYED IN HIDE(PD
[58]  PIJM[80;81]←(1-VAR[10])
[59] ⍝81 ON USED (DETECTED) POINT WITH MISSION LAYING          82,84,85,93
[60]  PIJM[81;93]←VAR[11]
[61]  PIJM[81;82]←(1-VAR[45])×(1-VAR[11])×VAR[12]
[62]  PIJM[81;84]←VAR[45]×(1-VAR[11])
[63] ⍝PROBABILITY OF SHOOTING WHEN READY
[64]  PIJM[81;85]←(1-VAR[45])×(1-VAR[11])×(1-VAR[12])
```

```
[65] ⍝82 ON USED (DETECTED) POINT LAID WAITING COMMAND      83,84,85,93
[66]  PIJM[82;93]←VAR[13]
[67]  PIJM[82;85]←(1-VAR[45])×(1-VAR[13])×VAR[14]
[68]  PIJM[82;84]←VAR[45]×(1-VAR[13])×VAR[14]
[69]  PIJM[82;83]←(1-VAR[13])×(1-VAR[14])
[70] ⍝83 ABORT MISSION GO TO NEW POINT                            68,71,93
[71]  PIJM[83;93]←VAR[15]
[72]  PIJM[83;68]←VAR[16]×(1-VAR[15])
[73] ⍝PROBABILITY OF GETTING TO POINT WITHOUT INCEDENT
[74]  PIJM[83;71]←(1-VAR[16])×(1-VAR[15])
[75] ⍝84 MISFIRE ON USED (DETECTED) POINT                         85,86,93
[76] ⍝ROUND FIRES ON SUBSEQUENT TRY
[77]  PIJM[84;85]←VAR[46]
[78]  PIJM[84;93]←(1-VAR[46])×VAR[17]
[79]  PIJM[84;86]←(1-VAR[46])×(1-VAR[17])
[80] ⍝85 MISSILE SHOT DISPLACING                                     86,93
[81]  PIJM[85;93]←VAR[21]
[82]  PIJM[85;86]←(1-VAR[21])
[83] ⍝86 ENROUTE TO BATTERY AREA TO TRANSLOAD                     87,88,90
[84]  PIJM[86;90]←VAR[50]
[85]  PIJM[86;87]←VAR[51]×(1-VAR[50])
[86] ⍝PROBABILITY OF ARRIVING AT TP
[87]  PIJM[86;88]←(1-VAR[51])×(1-VAR[50])
[88] ⍝87 DOWN WHILE ENROUTE TO TRANSLOAD POINT                       88,90
[89]  PIJM[87;90]←VAR[52]
[90] ⍝PROBABILBITY OF ARRIVING AT TRANSLOAD POINT
[91]  PIJM[87;88]←(1-VAR[52])
[92] ⍝88 TRANSLOADING AT TRANSLOAD POINT          1,3,9,11,67,69,75,77,91
[93]  PIJM[88;91]←VAR[53]
[94] ⍝PROBABILITY GOING TO A NEW POINT WITHOUT A MISSION'
[95]  PIJM[88;1]←(1-VAR[53])×(1-VAR[42])×VAR[47]×VAR[48]
[96]  PIJM[88;67]←(1-VAR[53])×(1-VAR[42])×VAR[47]×(1-VAR[48])
[97] ⍝PROBABILTY OF GOING TO A NEW POINT WITH A MISSION
[98]  PIJM[88;3]←(1-VAR[53])×VAR[42]×VAR[47]×VAR[48]
```

```
PIJM[88;69]←(1-VAR[53])×VAR[42]×VAR[47]×(1-VAR[48])
⍝PROBABILITY OF GOING TO A USED POINT WITHOUT A MISSION
 PIJM[88;9]←(1-VAR[53])×(1-VAR[42])×(1-VAR[47])×VAR[48]
 PIJM[88;11]←(1-VAR[53])×VAR[42]×(1-VAR[47])×VAR[48]
 PIJM[88;75]←(1-VAR[53])×(1-VAR[42])×(1-VAR[47])×(1-VAR[48])
 PIJM[88;77]←(1-VAR[53])×VAR[42]×(1-VAR[47])×(1-VAR[48])

⍝ABSORPTION STATES HAVE A PROBABILITY OF ONE OF REMAINING IN THAT
⍝STATE

 PIJM[89;89]←1
 PIJM[90;90]←1
 PIJM[91;91]←1
 PIJM[92;92]←1
 PIJM[93;93]←1
∇
```

APPENDIX K.

```
      ∇ PROGTIME
[1]   ⍝THIS PROGRAM ASKS THE PROGRAMMER FOR EXPECTED DURATIONS OF TIME FOR
[2]   ⍝EVENTS WHICH WILL BE USED TO CREATE THE T(I,J) MATRIX.  ALL VALUES ARE
[3]   ⍝STORED IN VECTOR 'TIME'.
[4]    ''
[5]    TIME←20⍴0
[6]    'ENTER THE FOLLOWING EXPECTED TIMES IN MINUTES'
[7]    'TRAVEL TIME BETWEEN LOCAL TRANSLOAD POINT AND A FIRE POINT'
[8]    TIME[1]←⎕
[9]    'EXPECTED TIME NEEDED TO RECOVER WHEN DOWN FOR MAINTENANCE EN ROUTE'
[10]   TIME[2]←⎕
[11]   'TIME WAITING IN HIDE POSITION UNTIL MISSION RECEIVED'
[12]   TIME[3]←⎕
[13]   'TIME TO TRAVEL FROM HIDE POSITION TO THE FIRE POINT AND LAY WEAPON'
[14]   TIME[4]←⎕
[15]   'TIME UNTIL RECEIVING COMMAND TO FIRE WHEN LAID AND WAITING'
[16]   TIME[5]←⎕
[17]   'TIME NEEDED TO CONDUCT MISFIRE PROCEDURES AND FIRE AGAIN'
[18]   TIME[6]←⎕
[19]   'TIME NEEDED TO CONDUCT MISFIRE PROCEDURES AND REJECT BAD ROUND'
[20]   TIME[7]←⎕
[21]   'TIME UNTIL RECEIVING COMMAND TO ABORT MISSION WHEN LAID AND DETECTED'
[22]   TIME[8]←⎕
[23]   'TIME TO DISPLACE WHEN ABORTING MISSION'
[24]   TIME[9]←⎕
[25]   'TIME TO DISPLACE AFTER ROUND IS FIRED'
[26]   TIME[10]←⎕
[27]   'TIME NEEDED TO TRANSLOAD AT A FIRE POINT AFTER A MISSION IS SHOT'
[28]   TIME[11]←⎕
[29]   'TIME NEEDED TO TRANSLOAD AT A FIRE POINT AFTER A MISFIRE (CON 1)'
[30]   TIME[12]←⎕
```

```
[31]  'TIME NEEDED TO TRANSLOAD EN ROUTE AND TRAVEL TO NEXT POINT (CON 1)
[32]  TIME[13]←⎕
[33]  'TRAVEL TIME BETWEEN BATTERY POSITION AND A FIRE POINT'
[34]  TIME[14]←⎕
[35]  'EXPECTED TIME TO TRANSLOAD AT TRANSLOAD POINT OR BATTERY POSITION'
[36]  TIME[15]←⎕
[37]  'TIME UNTIL BECOMING DETECTED WHILE IN HIDE POSITION'
[38]  '(UNDETECTED POINT)'
[39]  TIME[17]←⎕
[40]  'TIME UNTIL BECOMING DETECTED WHILE IN HIDE POSITION(DETECTED POINT
[41]  TIME[18]←⎕
[42]  'ADDITIONAL TIME IN DETECTED HIDE POSITION BEFORE MISSION RECEIVED'
[43]  TIME[19]←⎕
[44]  'TIME UNTIL BECOMING DETECTED WHILE LAID WAITING FOR A COMMAND TO'
[45]  'FIRE ON AN UNDETECTED FIRE POINT'
[46]  TIME[20]←⎕
[47]
      ∇
```

APPENDIX L.

```
      ∇ TIMEMTX
[1]   ⍝THIS PROGRAM USES VALUES STORED IN VECTOR 'TIME' TO COMPUTE T(I,J)
[2]   ⍝VALUES AND CREATE THE T(I,J) MATRIX (TIJM).
[3]   ⍝FIRST THE MATRIX IS CREATED
[4]    ''
[5]    TIJM← 93 93 ⍴0
[6]    ''
[7]   ⍝THEN THE VALUES ARE COMPUTED
[8]    ''
[9]   ⍝TRAVEL TIME BETWEEN TRANSLOAD POINT AND FIRE POINT
[10]   TIJM[1;(2,5)]←TIME[14]
[11]   TIJM[3;(4,6)]←TIME[14]
[12]   TIJM[34;(35,38)]←TIME[1]
[13]   TIJM[36;(37,39)]←TIME[1]
[14]   TIJM[9;(10,13)]←TIME[14]
[15]   TIJM[11;(12,15)]←TIME[14]
[16]   TIJM[42;(43,46)]←TIME[1]
[17]   TIJM[44;(45,48)]←TIME[1]
[18]   TIJM[67;(68,71)]←TIME[1]
[19]   TIJM[69;(70,72)]←TIME[1]
[20]   TIJM[75;(76,79)]←TIME[1]
[21]   TIJM[77;(78,81)]←TIME[1]
[22] ⍝TRANSLOAD POINT'
[23]   TIJM[(34,36,42,44,67,69,75,77);92]←0.5×TIME[1]
[24] ⍝TIME UNTIL BEING DESTROYED EN ROUTE TO FIRE POINT FROM
[25] ⍝BATTERY POSITION
[26]   TIJM[(1,3,9,11);92]←0.5×TIME[14]
[27] ⍝TIME UNTIL BEING DESTROYED EN ROUTE TO LOCAL TRANSLOAD POINT
[28] ⍝FROM FIRE POINT'
[29]   TIJM[(31,64);90]←0.5×TIME[1]
[30] ⍝TIME UNTIL BEING DESTROYED EN ROUTE TO BATTERY POSITION
```

```
[31] ⍝FROM FIRE POINT'
[32]  TIJM[86;90]←0.5×TIME[1]
[33] ⍝IF CONFIGURATION ONE ADJUST TRAVEL TIME TO FIRE POINT
[34]  →(VAR[49]≠3)ρLOOP3
[35]  TIJM[67;71]←TIME[14]
[36]  TIJM[69;72]←TIME[14]
[37]  TIJM[75;79]←TIME[14]
[38]  TIJM[77;81]←TIME[14]
[39]  TIJM[(67,69,75,77);92]←0.5×TIME[14]
[40] LOOP3: ⍝EXPECTED TRAVEL TIME FROM FIRE POINT TO TRANSLOAD POINT/BATT
[41]  TIJM[31;(32,33)]←TIME[1]
[42]  TIJM[64;(65,66)]←TIME[1]
[43]  TIJM[86;(87,88)]←TIME[14]
[44] ⍝EXPECTED TIME NEEDED TO RECOVER WHEN DOWN FOR MAINTENANCE EN ROUTE
[45]  TIJM[2;5]←TIME[2]
[46]  TIJM[4;(5,6)]←TIME[2]
[47]  TIJM[10;13]←TIME[2]
[48]  TIJM[12;(13,15)]←TIME[2]
[49]  TIJM[24;38]←TIME[2]
[50]  TIJM[26;39]←TIME[2]
[51]  TIJM[28;46]←TIME[2]
[52]  TIJM[30;48]←TIME[2]
[53]  TIJM[32;33]←TIME[2]
[54]  TIJM[35;38]←TIME[2]
[55]  TIJM[37;(38,39)]←TIME[2]
[56]  TIJM[43;46]←TIME[2]
[57]  TIJM[45;(46,47)]←TIME[2]
[58]  TIJM[57;71]←TIME[2]
[59]  TIJM[59;72]←TIME[2]
[60]  TIJM[61;79]←TIME[2]
[61]  TIJM[63;81]←TIME[2]
[62]  TIJM[65;66]←TIME[2]
[63]  TIJM[68;71]←TIME[2]
[64]  TIJM[70;(71,72)]←TIME[2]
```

```
[65]  TIJM[76;79]←TIME[2]
[66]  TIJM[78;(79,81)]←TIME[2]
[67]  TIJM[87;88]←TIME[2]
[68] ⍝TIME UNTIL BEING DESTROYED WHILE BROKEN DOWN
[69]  TIJM[(2,4,10,12);92]←0.5×TIME[2]
[70]  TIJM[(35,37,43,45);92]←0.5×TIME[2]
[71]  TIJM[(68,70,76,78);92]←0.5×TIME[2]
[72]  TIJM[(24,26,28,30,32);89]←0.5×TIME[2]
[73]  TIJM[(57,59,61,63,65);89]←0.5×TIME[2]
[74]  TIJM[87;90]←0.5×TIME[2]
[75] ⍝TIME WAITING IN HIDE POSITION UNTIL MISSION RECIEVED
[76]  TIJM[5;6]←TIME[3]
[77]  TIJM[13;15]←TIME[3]
[78]  TIJM[38;39]←TIME[3]
[79]  TIJM[46;48]←TIME[3]
[80]  TIJM[71;72]←TIME[3]
[81]  TIJM[79;81]←TIME[3]
[82] ⍝TIME WAITING IN HIDE POSITION UNTIL DETECTED
[83]  TIJM[5;14]←0.5×TIME[3]
[84]  TIJM[13;14]←0.5×TIME[3]
[85]  TIJM[38;47]←0.5×TIME[3]
[86]  TIJM[47;48]←0.5×TIME[3]
[87]  TIJM[71;80]←0.5×TIME[3]
[88]  TIJM[79;80]←0.5×TIME[3]
[89] ⍝TIME NEEDED TO LAY WEAPON
[90]  TIJM[6;(7,8,19)]←TIME[4]
[91]  TIJM[15;(16,18,19)]←TIME[4]
[92]  TIJM[39;(40,41,52)]←TIME[4]
[93]  TIJM[48;(49,51,52)]←TIME[4]
[94]  TIJM[72;(73,74,85)]←TIME[4]
[95]  TIJM[81;(82,84,85)]←TIME[4]
[96] ⍝TIME UNTIL RECEIVING COMMAND TO FIRE (LAID AND WAITING)
[97]  TIJM[7;(8,19)]←TIME[5]
[98]  TIJM[16;(18,19)]←TIME[5]
```

```
[99]  TIJM[40;(41,52)]←TIME[5]
[100]  TIJM[49;(51,52)]←TIME[5]
[101]  TIJM[73;(74,85)]←TIME[5]
[102]  TIJM[82;(84,85)]←TIME[5]
[103] ⍝TIME NEEDED TO CONDUCT MISFIRE PROCEEDURES AND FIRE AGAIN
[104]  TIJM[8;19]←TIME[6]
[105]  TIJM[18;19]←TIME[6]
[106]  TIJM[41;52]←TIME[6]
[107]  TIJM[51;52]←TIME[6]
[108]  TIJM[74;85]←TIME[6]
[109]  TIJM[84;85]←TIME[6]
[110] ⍝TIME NEEDED TO CONDUCT MISFIRE PROCEEDURES AND REJECT BAD ROUND
[111]  TIJM[8;(22,31)]←TIME[7]
[112]  TIJM[18;(21,23,25,27,29,31)]←TIME[7]
[113]  TIJM[41;(55,64)]←TIME[7]
[114]  TIJM[51;(54,56,58,60,62,64)]←TIME[7]
[115]  TIJM[74;86]←TIME[7]
[116]  TIJM[84;86]←TIME[7]
[117] ⍝TIME UNTIL RECEIVING COMMAND TO ABORT MISSION WHEN LAID DETECTED
[118]  TIJM[16;17]←TIME[8]
[119]  TIJM[49;50]←TIME[8]
[120]  TIJM[82;83]←TIME[8]
[121] ⍝TIME TO DISPLACE (ABORT MISSION)
[122]  TIJM[17;(2,5)]←TIME[9]
[123]  TIJM[50;(35,38)]←TIME[9]
[124]  TIJM[83;(68,71)]←TIME[9]
[125] ⍝TIME TO DISPLACE AFTER ROUND IS FIRED
[126]  TIJM[19;(20,23,25,27,29,31)]←TIME[10]
[127]  TIJM[52;(53,56,58,60,62,64)]←TIME[10]
[128]  TIJM[85;86]←TIME[10]
[129] ⍝TIME NEEDED TO TRANSLOAD AT A FIRE POINT AFTER A MISSION IS SHOT
[130]  TIJM[20;(47,48)]←TIME[11]
[131]  TIJM[53;(80,81)]←TIME[11]
[132] ⍝TIME NEEDED TO TRANSLOAD AT A FIRE POINT AFTER A MISFIRE
```

```
[133]  TIJM[21;(46,48)]←TIME[12]
[134]  TIJM[22;(38,39,47,48)]←TIME[12]
[135]  TIJM[54;(79,81)]←TIME[12]
[136]  TIJM[55;(71,72,80,81)]←TIME[12]
[137] ⍝TIME NEEDED TO TRANSLOAD EN ROUTE AND TRAVEL TO NEW POINT
[138]  TIJM[23;(38,24)]←TIME[13]
[139]  TIJM[56;(71,57)]←TIME[13]
[140]  TIJM[58;(59,72)]←TIME[13]
[141]  TIJM[25;(39,26)]←TIME[13]
[142]  TIJM[27;(46,28)]←TIME[13]
[143]  TIJM[60;(79,61)]←TIME[13]
[144]  TIJM[29;(48,30)]←TIME[13]
[145]  TIJM[62;(81,63)]←TIME[13]
[146]  TIJM[33;(34,36,42,44)]←TIME[13]
[147] ⍝EXPECTED TIME TRANSLOADING AT TRANSLOAD POINT/BATTERY POSITION
[148]  TIJM[33;(34,36,42,44)]←TIME[15]
[149]  TIJM[66;(67,69,75,77)]←TIME[15]
[150]  TIJM[88;(1,3,9,11,67,69,75,77)]←TIME[15]
[151] ⍝TIME UNTIL BEING DESTROYED WHILE TRANSLOADING
[152]  TIJM[(33,66,88);93]←0.5×TIME[15]
[153] ⍝TIME UNTIL BECOMING DETECTED WHILE IN HIDE POSITION(UNUSED POINT)
[154]  TIJM[5;14]←TIME[17]
[155]  TIJM[38;47]←TIME[17]
[156]  TIJM[71;80]←TIME[17]
[157] ⍝TIME UNTIL BECOMING DETECTED WHILE IN HIDE POSITION(USED POINT)
[158]  TIJM[13;14]←TIME[18]
[159]  TIJM[46;47]←TIME[18]
[160]  TIJM[79;80]←TIME[18]
[161] ⍝ADDITIONAL TIME IN DETECTED HIDE POSITION BEFORE MISSION RECEIVED
[162]  TIJM[14;15]←TIME[19]
[163]  TIJM[47;48]←TIME[19]
[164]  TIJM[80;81]←TIME[19]
[165] ⍝TIME UNTIL DETECTION WHILE LAID WAITING AT UNDETECTED FIRE POINT
[166]  TIJM[7;16]←TIME[20]
```

```
[167]  TIJM[40;49]←TIME[20]
[168]  TIJM[73;82]←TIME[20]
[169] ⍝TIME UNTIL BEING DESTROYED WHILE HIDING
[170]  TIJM[(14,47,80);93]←0.5×TIME[3]
[171] ⍝TIME UNTIL BEING DESTROYED WHILE LAID WAITING FOR COMMAND TO FIRE
[172]  TIJM[(16,49,82);93]←0.5×TIME[5]
[173] ⍝TIME UNTIL BEING DESTROYED WHILE TRANSLOADING EN ROUTE TO
[174] ⍝FIRE POINT
[175]  TIJM[(23,25,56,58);89]←0.5×TIME[13]
[176] ⍝TIME UNTIL BEING DESTROYED BEFORE DEPARTING A FIRE POINT
[177] ⍝AFTER A MISSION
[178]  TIJM[(18,19,51,52,84,85);93]←0.5×TIME[10]
[179] ⍝TIME UNTIL BEING DESTROYED WHILE TRANSLOADING AT A FIRE POINT'
[180] ⍝AFTER A MISSION
[181]  TIJM[(20,53);93]←0.5×TIME[11]
[182] ⍝TIME UNTIL BEING DESTROYED WHILE TRANSLOADING AT A FIRE POINT'
[183]  TIJM[(21,22,54,55);93]←0.5×TIME[12]
      ∇
```

APPENDIX M.

```
∇ SOLVE;TABST;I;Q;U;W;R
⍝THIS FUNCTION USES TRANSITION AND TIME MATRICES ASSOCIATED
⍝WITH THE MARKOV CHAIN TO SOLVE FOR THE EXPECTED TIME TO ABSORPTION
⍝AND THE EXPECTED NUMBER OF VISITS TO A TRANSIENT STATE PRIORTY
⍝ABSORPTION.
⍝ COMPUTE COMPONENTS OF P:
 R← 88 ¯5 ↑PIJM
⍝ CREATE FUNDAMENTAL MATRIX
 Q← 88 88 ↑PIJM
 I← 88 88 ρ1,88ρ0
 W←⌹(I-Q)
⍝ ASSIGN PROBABILITIES OF ABSORPTION
 U←W+.×R
⍝ COMPUTE MEAN SOJOURN TIME FOR EACH STATE
 MST←¯5↓+/PIJM×TIJM
⍝ COMPUTE EXPECTED TIME TO ABSORPTION FROM A GIVEN STATE
 TABST←(W+.×MST)÷60
 ''
⍝HERE THE NUMBER OF MISSILES FIRED IS COMPUTED ACCORDING TO THE
⍝CONFIGURATION.  CONFIGURATION ONE AND TWO START IN STATE 5 AND
⍝HAVE SHOT A MISSILE EACH TIME THEY REACH STATES 19, 52, AND 85.
⍝CONFIGURATION TWO STARTS IN CONFIGURATION 71 AND HAS SHOT A MISSILE
⍝EACH TIME IT REACHES STATE 85.
 ''
⍝COMPUTE THE NUMBER OF MISSILES FIRED
 →(VAR[49]=3)ρLOOP
⍝CONFIGURATION ONE OR TWO
 NUMROUND←W[5;19]+W[5;52]+W[5;85]
 TABS←TABST[5]
 'NUMBER OF MISSILES FIRED EQUALS'
 NUMROUND
```

```
[31]  'TIME UNTIL ABSORPTION EQUALS'
[32]  TABS
[33]  TABS÷NUMROUND
[34]  →0
[35] LOOP: ⍝COMPUTE THE NUMBER OF ROUNDS FIRED
[36] ⍝CONFIGURATION THREE
[37]  NUMROUND←W[71;85]
[38]  TABS←TABST[71]
[39]  'NUMBER OF MISSILES FIRED EQUALS'
[40]  NUMROUND
[41]  'TIME UNTIL ABSORPTION EQUALS'
[42]  TABS
[43]  TABS÷NUMROUND
      ∇
```

APPENDIX N.

```
    ∇ CONFIGURE
  ⍝THIS PROGRAM ALLOWS THE USER TO CHANGE THE CONFIGURATION OF THE
  ⍝LAUNCHER WITHOUT ALTERING OTHER INPUT DATA.  ONCE THE
  ⍝CHANGE IS ENTERED A NEW 'P' MATRIX AND 'T' MATRIX ARE COMPUTED.
   ''
   'ENTER CONFIGURATION (1, 2 OR 3)'
   VAR[49]←⎕
  ⍝CONFIGURATION 1
   →(VAR[49]≠1)⍴LOOP1
   VAR[(8,19,23,48)]←1
   →LOOP3
  LOOP1: ⍝CONFIGURATION 2
   →(VAR[49]≠2)⍴LOOP2
   VAR[(8,19,23)]←0
   VAR[48]←1
   →LOOP3
  LOOP2: ⍝CONFIGURATION 3
   VAR[(8,19,23,48)]←0
  LOOP3: ⍝RECOMPUTE PIJM AND TIJM
   PROG1MTX
   PROG2MTX
   PROG3MTX
   TIMEMTX
    ∇
```

LIST OF REFERENCES

1. Hughes, W. P. Jr., *Military Modeling*, The Military Operations Research Soeiety, 1984.

2. Taylor, H. M. and Karlin, S *An Introduction to Stochastic Modeling*, Academic Press, Inc., 1984.

3. Ross, S. M., *Introduction to Probability Models*, Academic Press, Inc., 1985.

BIBLIOGRAPHY

Taylor, H. M. and Karlin, S *An Introduction to Stochastic Modeling,* Academic Press, Inc., 1984.

Hughes, W. P. Jr., *Military Modeling,* The Military Operations Research Soeiety, 1984.

Ross, S. M., *Introduction to Probability Models,* Academic Press, Inc., 1985.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, VA 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, CA 93943-5002	2
3.	Deputy Undersecretary of the Army for Operations Research Room 2E261, The Pentagon Washington, D.C. 20310	2
4.	Director Attn: Mr. E.B. Vandiver III U.S. Army Concepts Analysis Agency Bethesda, MD 20814	2
5.	Director Requirements & Programs Director Headquarters, USA-TRADOC Attn: ATRC-RP (COL Brinkley) Fort Monroe, VA 23651-5143	2
6.	Commander U.S. Army TRADOC Analysis Command Attn: ATRC Fort Leavenworth, KS 66027-5200	1
7.	Commander and Director U.S. Army TRADOC Analysis Command TRAC-Monterey Monterey, CA 93943	5
8.	Commander and Director U.S. Army TRADOC Analysis Command TRAC-FLVN Attn: ATRC-F (Dr. LaRocque) Fort Leavenworth, KS 66027-5200	2
9.	Commander and Director U.S. Army TRADOC Analysis Command TRAC-FLVN Attn: ATRC-ZD (Mr. Bauman) Fort Leavenworth, KS 66027-5200	1

10. Commander and Director 1
U.S. Army TRADOC Analysis Command
TRAC-WSMR
Attn: ATRC-W (Dr. Collier)
White Sands Missle Range, NM 88002-5502

11. Commander and Director 2
U.S. Army TRADOC Analysis Command
TRAC-WSMR
Attn: ATRC-RD (Mr. Hue McCoy)
White Sands Missle Range, NM 88002-5502

12. Commander and Director 1
U.S. Army TRADOC Analysis Command
TRAC-LEE
Attn: ATRC-LC
Fort Lee, VA 23801-6000

13. Professor Samuel H. Parry 5
Department of Operations Research
Naval Postgraduate School, Code 55Py
Monterey, CA 93943-5000

14. Professor Patricia A. Jacobs 1
Department of Operations Research
Naval Postgraduate School, Code 55Jc
Monterey, CA 93943-5000

15. Captain(P) Harry M. Argo 5
9393 Ludgate Drive
Alexandria, VA 22309

16. Chief Defense Scientist Office 2
Operations Analysis Department
Attn: Sim Cheng Hwee
Ministry of Defense
Mindef Building, Sombak Drive
Singapore 2366
The Republic of Singapore

17. Superintendent 1
U.S. Naval Academy
Attn: (Major T.J Meyers)
Annapolis, MD 21402

18. Major John M. Misiewicz 1
MAGTF Warfighting Center (WF13)
Marine Corps Combat Development Command
Quantico, VA 22134-5001